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No. 51

PRINCIPLES AND PRACTICE OF ASSEMBLING MACHINE TOOLS

PART II

By ALFRED SPANGENBERG

CONTENTS

Assembling an Engine Lathe - - - - - - - 3
Assembling a Motor-Driven Planer - - - - - 16
Laying-out and Aligning Operations - - - - - 32

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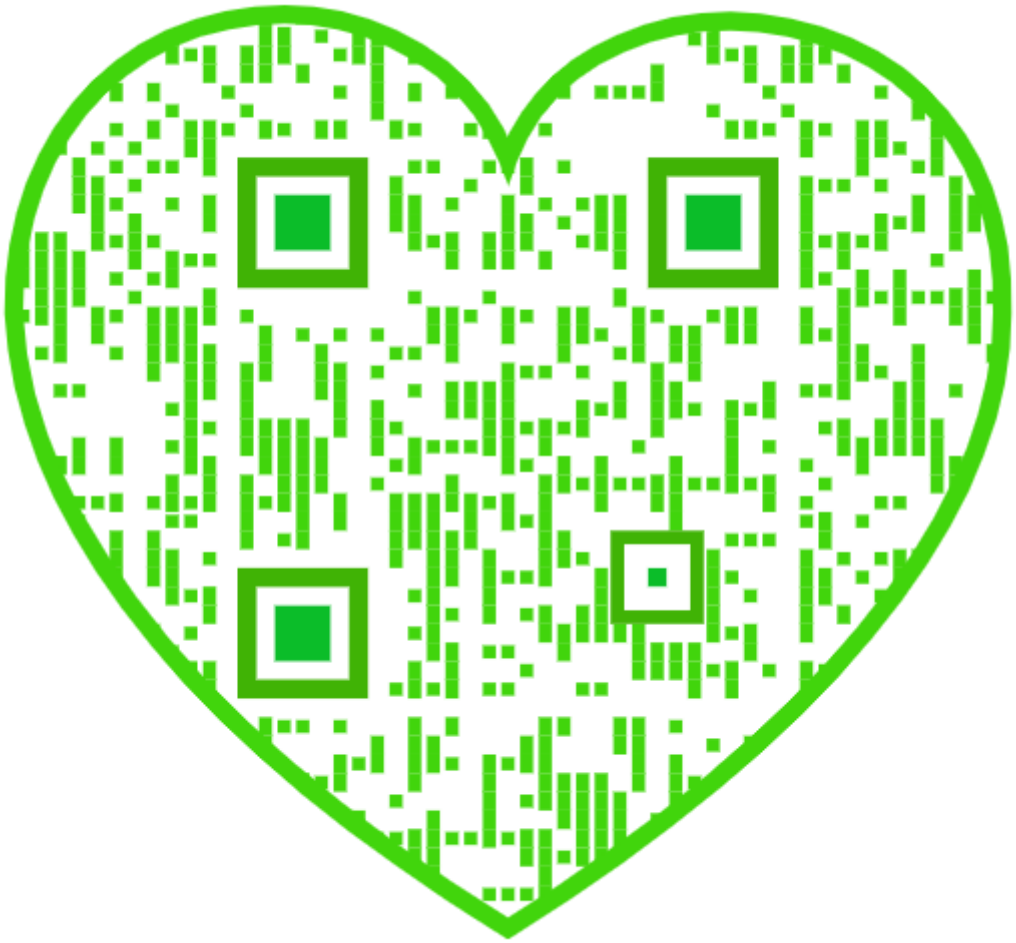

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CHAPTER I

ASSEMBLING AN ENGINE LATHE*

While the problems encountered in assembling engine lathes are not as difficult of solution as those met with in assembling machine tools of a more complicated nature, thorough and careful consideration of the methods employed is essential in order to minimize the cost. The most important operations involved are the scraping of the bed and carriage and the lining up of the head- and tail-stock. To a large extent the cost of these operations is dependent on the accuracy of the machine work.

It is the object of the present chapter to discuss the methods employed in machining, and to illustrate and describe the erecting process on the bed. The principles involved in assembling the units have been fully outlined in Part I of this treatise. (MACHINERY'S Reference Series No. 50.) For the purpose of giving a concrete example, a 24-inch engine lathe with quick-change gear device is selected, the general features of which are shown in Fig. 1.

Planing the Bed and Carriage

The practice of some makers to rough out the surfaces to be planed on the bed and carriage, and allow them to season before taking the finishing cuts is indicative of the modern tendency toward accurate machine work as a means to avoid unnecessary scraping. The seasoning process simply consists in letting the casting stand in some convenient place in such a way that it will not be subjected to any outside forces, and allowing the stresses in the casting itself to become equalized.

Next in importance to providing accurate planers on which to machine the bed and carriage, is the necessity for gages that will enable interchangeable work to be produced. The gages shown in Fig. 2 are particularly well adapted to this class of work, and are far superior to the common type having a bearing on both sides of each V. Feelers or thickness gages are used in connection with the gages illustrated, in order to measure the amount of error. The advantages this form possesses over the common type are that the V's on the casting being fitted will both be of the same width, and no difficulty is experienced in keeping the gage level, since it always lies in a horizontal plane by resting on the top of each V. At *A* and *B* are shown gages for the bed and carriage respectively; these gages are made of steel ¼ inch thick.

Assuming, for example, that the V-surface on the bed at *C* is tight to the gage, and a 0.002 inch feeler will just pass between the bed and the gage at *D*, then 0.002 is the exact amount that must be planed off the surface *C*. When these two surfaces fit the gage so that no error

*MACHINERY, November, 1909.

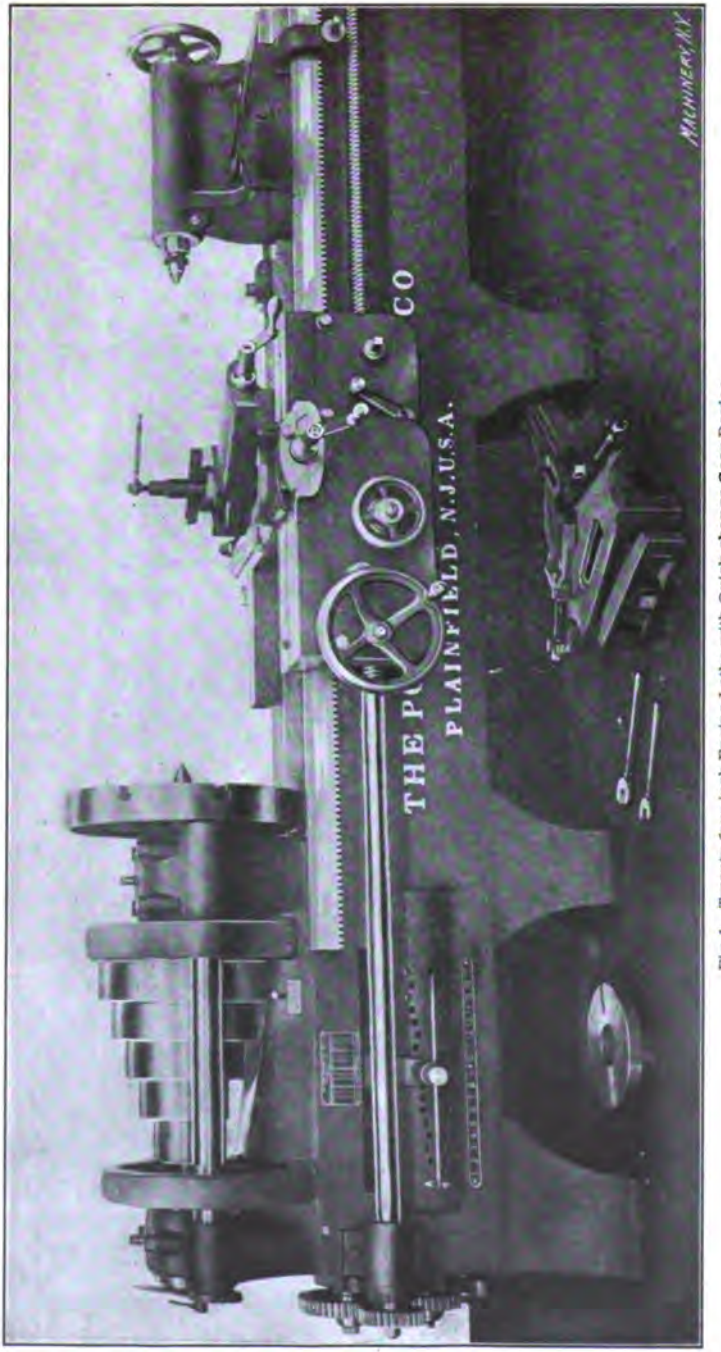

Fig. 1. Twenty-four-inch Engine Lathe with Quick-change Gear Device

can be detected with a 0.001 feeler, the gage is turned end for end, and the surfaces *E* and *F* are tested in the same manner. It is, of course, necessary to set the gage square with the bed and this is accomplished by trying the feelers on both sides of the gage. The same remarks apply to the carriage gage *B*. At *G* and *H* in the same engraving are shown gages in the form of cast-iron blocks about 6 inches long which are used for testing the ways on bed and carriage as indicated; *I* is a sheet steel strip fastened to one end of gage *H* and this is used to test the apron seat *J*. All other measurements are tested with ordinary height blocks or caliper gages, as the case may require.

Referring now to the carriage, the sequence of operations in finish planing it is to plane the bearing for the shoe, and square up the ends, and then turn it over in the position shown in the engraving and plane the V's and other surfaces on this side. It is good practice to plane lathe carriages of this size in lots of six at a time by placing them in

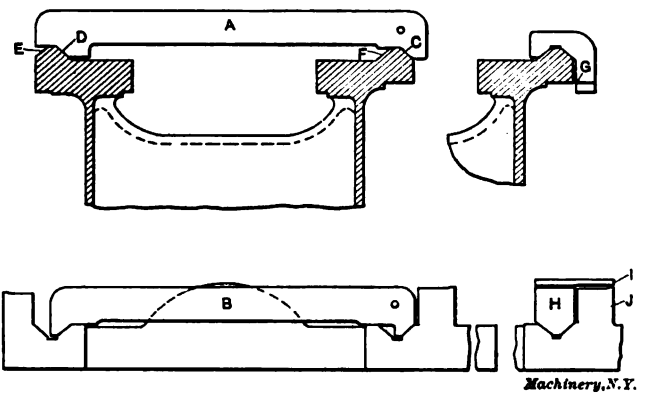

Fig. 2. Gages for Testing the Planing of Lathe Bed and Carriage

a "string" on the planer table. When completing the final operation, that of planing the V's, it is evident, however, that the carriages farthest away from the angle plate by which they are squared up, are particularly liable to error. With careful setting up, this error should not exceed 0.003 inch, which is easily and quickly scraped off by the assemblers.

Machining the Head- and Tail-stock

The methods of machining head- and tail-stocks vary greatly in different shops, and also with different sizes. Some makers first finish all the planing and then perform the boring operations and scrape in the head-stock spindle, while others leave a finishing cut to be taken on the bottom of the head- and tail-stock after the boring and scraping are completed, by setting up the castings on arbors held in V-blocks on the planer table. Both systems, or modifications of both, are frequently used in the same shop. While the first-mentioned system is the most economical in that it saves setting up the work on the planer twice, it is essential that the machining be such that very little scrap-

ing is required on the head-stock boxes; otherwise the head-stock will be thrown out of line in fitting the spindle, which necessitates replaning the head-stock and possibly the tail-stock.

In any event, it will always pay to leave 1/16 inch stock to be bored out of the bearing boxes, so that after the boxes are fitted in the head-stock it can be replaced in the boring jig and a finishing cut taken in the boxes, allowing 0.005 inch to be reamed out. Adjustable shell reamers are mounted on the boring bar for this purpose. When this precaution is taken, and the spindle is accurately ground to size, very little scraping should be necessary to make a good bearing. The object of leaving the 1/16 inch to be bored out with a cutter before ream-

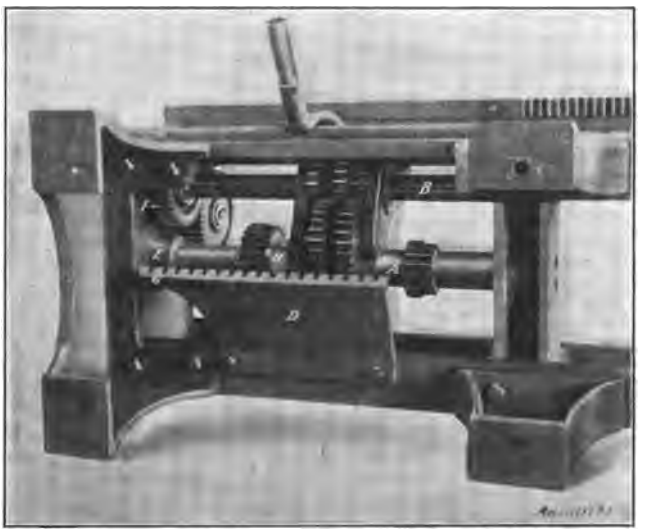

Fig. 8. Quick-change Gear Mechanism of Lathe shown in Fig. 1

ing, is to insure that the reamer has an even cut and that sufficient stock is left for reaming.

Boring and Drilling the Bed

When all the planing is finished on the bed, it is next sent to the drilling department where the first operation consists in boring the shaft holes for the tumbler mechanism shown in Fig. 3. This operation is performed on a horizontal drilling and boring machine with the aid of a jig which also locates the sweep clamping bolt hole. The shafts *A* and *B* run in long cast-iron bushings that are a light drive fit in the bed, and to provide for standardization and enable the bushings to be finished in large quantities, the holes in the bed are reamed to gage, adjustable shell reamers being mounted in the boring bar for this purpose. The hole for stud *C* is drilled and then finished with a rose reamer, after which it is hand reamed to gage. This hole and the sweep clamping bolt hole are the only ones that require facing, the method of taking the measurements being apparent from Fig. 4; *A*

is a sheet-iron templet having an outline indicated by the heavy line; the opening at *B* locates the surface to which the stud boss is faced, while at *C* is shown whether there is sufficient clearance cored out for a feed gear. The templet is located sidewise by the spline *D* which is riveted to the templet and fits the keyway in the bed; and endwise by being brought flush with the end of the bed. When in this position lines are scribed at *B* and *C*, after which the templet is removed and the hole counterbored to the line; *C* is chipped out later on if necessary.

To locate the surface *E* for the sweep clamping bolt hole, the gage *F* is used, its construction being clearly shown in Fig. 4. All lateral measurements on the bed are taken from the surface *B*. Facing surface *E* completes the operations for this setting, and the bed is then moved around for drilling and tapping the lead-screw box bolt holes.

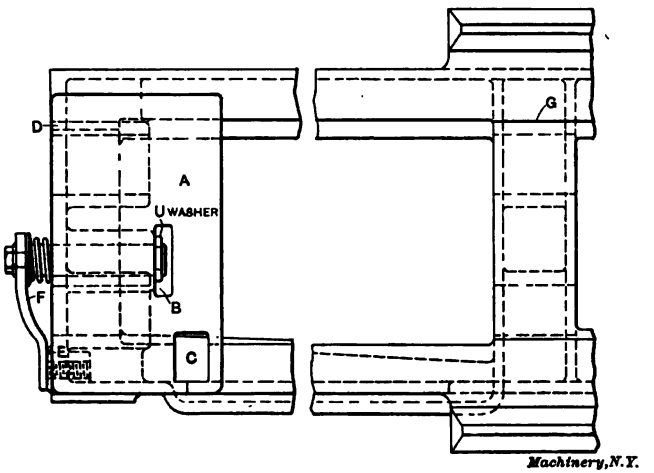

Fig. 4. Templet and Gage used when Boring the Bed, shown in Position

In Fig. 12, *A* and *B* are jigs for drilling the front and rear lead-screw box seats, respectively. As will be seen, both jigs are located from the flat surface on top of the bed, the rear jig clearing the front V. Jig *A* is located endwise by seating against the hub *C*; the wooden pole *D* is used to set jig *B*. This pole has lines cut on one side, giving the settings for various lengths of beds up to 16 feet, so that the distance between the boxes, when bolted on, will be correct for the lead-screw. For longer beds, especially those in two sections, jig *B* is set from the rear end of the bed, and after the boxes are bolted on, the measurement is taken for the length to cut the lead-screw; it is not practicable to set the rear box or cut the lead-screw in the same way in this case as in the previous one, due to the error that is likely to occur in the length of the bed. This completes the work at the horizontal drill, and the bed is now moved to a radial drill, where the holes for the rack are next drilled. Special eccentric clamps are used for

holding the rack in place, one of which is seen resting on top of the bed in Fig. 5. The advantages of this clamp over the common C-form are that it does not mar the work, no copper packing is needed, the clamping and loosening is quickly accomplished, and there is no danger of shifting the rack when clamping it.

When the holes for the rack are all drilled, including the pin holes, the drill-hand taps and enters one screw in each rack section, so as to keep the rack in place after the clamps are removed, and until the bed reaches the assemblers. This avoids tying up the radial drill while the rack is being fastened on the bed, which is the practice in some shops.

On top of the bed in Fig. 5 are shown two fixtures *A* and *B*, respectively, which are used to locate the tumbler locking bar *D*, Fig. 3. Fix-

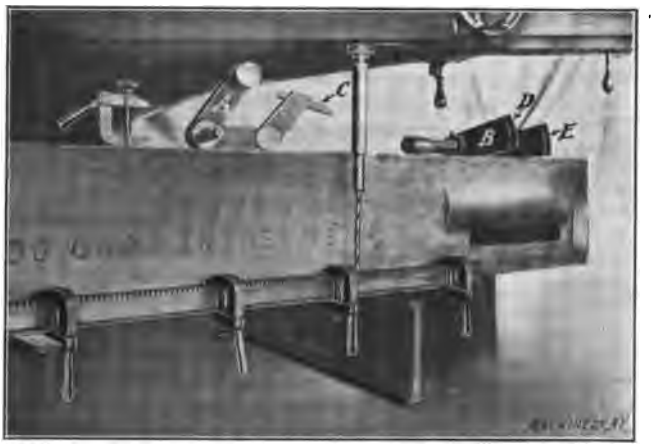

Fig. 5. Special Clamps for Holding Rack in Position when Drilling, and Fixtures used for Locating Tumbler Locking Plate

ture *A* is also used to set the bushings *E* and *F*, Fig. 3, by inserting the stud in the fixture in place of the stud *C*, and bringing the bushings (which are straight) up against the hubs shown on the fixture. Now, with fixture *B* in position in the tumbler shaft hole, the locking bar is set so that its first notch *G*, Fig. 3, fits over the projection *C* of fixture *A*, Fig. 5. The plates *D* and *E* on fixture *B* are then moved so as to enter slots near the ends of the locking bar, after which the locking bar is set so that its slots bottom in the fixture plates. In this position the bar is marked off, and after drilling the two bolt holes, which have 1/16-inch clearance, it is again placed in position and clamped by its bolts. It is then shifted so as to bring it in the correct relation to the fixtures, and then the pin holes are drilled. With the bushings *E* and *F* (Fig. 3) located as previously mentioned, their set-screw holes are now drilled.

The legs are set and marked off on the bed with the aid of a wooden pole having lines scribed on it representing the center line of each inner leg. After these holes are drilled and tapped and the legs bolted

on, the bed is next turned right side up for drilling the head-stock clamping bolt holes. The jig for drilling these holes is located on the bed by the keyway *D*, surface *G*, and hub *B*, Fig. 4, so that when the head-stock, which also was drilled by this jig, is bolted on, the feed gear on the spindle will line up with the intermediate feed gear in the bed, and the head-stock casting will match the end of the bed. This completes the drilling, and the bed is next sent to the assemblers, where the actual work of assembling proper begins.

Scraping the Carriage and Assembling the Tumbler Mechanism

It is the general practice to keep the head-stocks, tail-stocks, carriages, tumbler members, etc., in stock, completely assembled, these units being identical for any length of bed. This method will be considered here, it being assumed that the units already have been brought to the assemblers. Two men usually are employed in assembling a lathe of this size, since a larger number cannot advantageously be used. Two men should be able to assemble such a lathe in 40 hours, total time. The operations of scraping on the carriage and assembling the tumbler mechanism are, of course, carried on simultaneously, one man working on each job; but for the purpose of description, each operation will be considered separately.

The preliminary operations on the bed consist of rough scraping the V's and inside bearing for the tail-stock, fastening on the rack, and polishing the sides and top. When fastening on the rack, and polishing the sides, the bed is turned over for the convenience of the workmen. The rack, which was temporarily fastened on by the drill-hand, is now removed and all the holes tapped, after which it is screwed fast, the pin holes reamed, and the pins driven in. A carpenter's brace is used for the taps and reamer. As the rack already has been polished on a disk grinder, it is only necessary to rub it with emery cloth to obtain a good finish. The bed is now turned right side up and carefully leveled, using iron wedges. During these preliminary operations the painting and any necessary chipping is done.

For scraping the carriage to fit the bed a special lifting device is used to facilitate turning the carriage over. This device is described by the author in MACHINERY'S Reference Series No. 50. When the carriage is being pulled along the bed for the purpose of finding the bearing, the lifter bolts are slackened off so as to prevent any danger of springing the carriage.

Fig. 6 clearly indicates the method of squaring the carriage with the bed. As will be seen, the sweep bar *A* is held in firm contact with the angle and bottom bearing of the carriage by means of two flat steel springs *B*, bent to the shape shown. Brass shoes *C*, riveted to these springs, prevent the latter from cutting or scratching the bar. The function of coiled spring *D* is to hold the sweep bar collar *E* in close contact with the end of the carriage. With this device, the sweep is easily and quickly applied or removed, more precise measurements are obtained than by having an operator hold it, as is the usual practice; and besides, only one man is required to perform the operation of testing. In

operation, micrometer point *F* is set to one position as shown, using a piece of cigarette paper as a "feeler"; then the sweep is rotated to the opposite side and a measurement taken as before. The carriage is scraped so as to turn the face-plate about 0.001 inch concave.

Very little scraping is necessary on the bed, merely enough to smooth the V's and break up the bearing, the tool marks being visible after the scraping is completed. When this work is accomplished, the carriage gibs are fitted, the apron is bolted in place, and the cross-feed screw, shoe, etc., are placed in position. Next, the tail-stock cricket is placed on the bed and its packing fitted, after which it is pulled the entire length of the bed to determine if the latter is straight. After any high spots on the bed are scraped off, the tail-stock traverse bracket

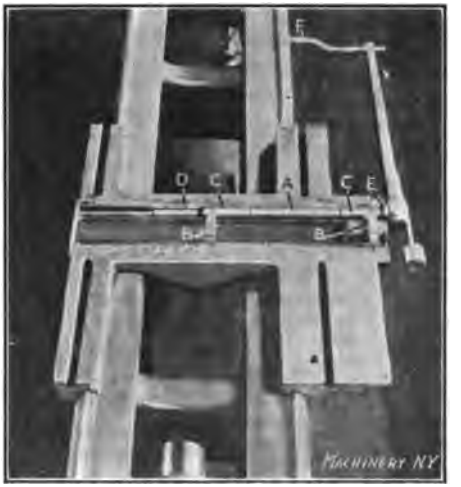

Fig. 6. Top View of Carriage, showing Method of Squaring the Carriage with the Bed. Springs B and D hold the Sweep in Position, enabling One Man to make the Test

is bolted onto the cricket, and then the tail-stock and its shoes are placed in position.

Referring again to Fig. 3, the tumbler mechanism is assembled in the bed as shown in the illustration, the operation being so simple that no explanation is necessary. Holes in the bed for the oil pipes (not shown) are drilled by means of a pneumatic drill, this being done, of course, preceding the assembling operation. The slot in the interlocking plate *H* is now marked off, the plate removed, and the slot cut. The position of this slot is determined by having the tumbler gears in a central position between the largest change gears. With the interlocking plate again screwed onto the tumbler, the thirty-four holes in the bed for the tumbler locking pin are now ready to be drilled.

Drilling these holes is the most interesting operation on this part of the lathe, the manner of accomplishing it being immediately ap-

parent from Fig. 7, which shows the tools used, some of them being seen on top of the bed. The method of holding the tumbler in engagement with the various change gears while drilling the holes in the bed is clearly shown in Fig. 8. Paper, to the thickness of about 0.005 inch, is placed between the teeth of the engaging gears before they are brought into mesh, and when the jack screw *A* is tightened sufficiently to hold the tumbler rigidly in place, the gears are in proper mesh. The holes are first drilled with a special drill that fits the locking pin hole in the tumbler and has flutes milled only a short distance up from the point, so as to avoid cutting the hole in the tumbler. Fig. 7 shows this drill in position in the air drill. For finishing the holes, a special rose reamer, shown at *B*, is used in the same manner.

The tools are fed into the work by means of the bar *C*, which is pointed on one end so that it can be driven into the floor to prevent

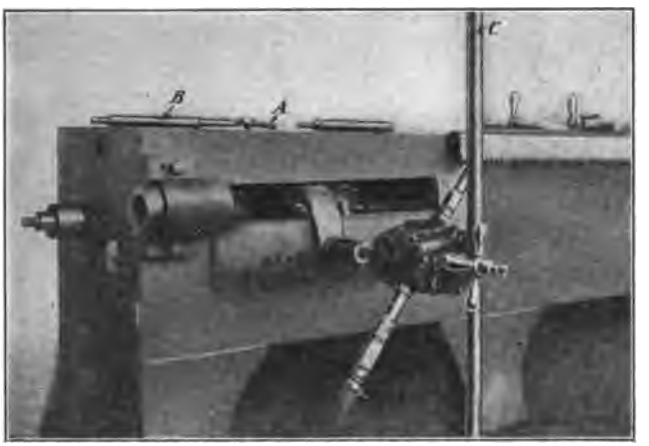

Fig. 7. Method of Drilling and Reaming the Holes in the Lathe Bed for the Tumbler Locking Pins

slipping. The operator presses his shoulder against the upper end of the bar, holds the throttle of the air drill with the left hand and pulls on the bed with the right hand. Each hole is drilled in succession, alternating between the top and bottom rows. The record for drilling and reaming these thirty-four holes, including the time required to set the tumbler, is 50 minutes. In setting the tumbler for drilling, its lateral movement for the various positions is controlled by the interlocking plate engaging the respective slots in the locking bar. (See Fig. 8.)

To mark off the groove which is seen between the two rows of holes in Fig. 1, a special scriber is used that fits the tumbler locking-pin hole, the tumbler being held in a neutral position by the locking bar. Two circles are scribed, one at each end of the groove to be cut, and then a straightedge is used in scribing lines connecting the two, the lines acting as a guide when chipping the groove with an air hammer.

Inserting the handle, chipping the groove, and fastening on the number and index plates completes the operation on the tumbler mechanism.

Lining Up the Head-stock and Tail-stock

The bed is now ready to receive the head-stock and while this is being fitted on by one of the assemblers, the other is working on the lead-screw, lead-screw boxes, and change gear sweep. As the head- and tail-stock were tested for alignment before being sent to the store-room, it is now only necessary to line up the head-stock on the bed and fit the taper dowel pins.

The method of testing these parts is interesting, inasmuch as the test arbor used is somewhat out of the ordinary. A jig is used that represents the head-end section of a 24-inch lathe bed. The jig and whole outfit of fixtures used, together with a head- and tail-stock in

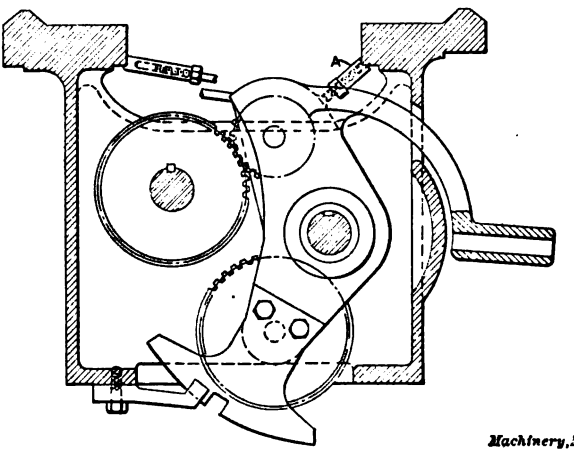

Fig. 8. Method of Holding Tumbler when Drilling and Reaming the Locking Pin Holes by the Method shown in Fig. 7

position for testing, are shown in Fig. 9. As will be seen, the test bar is square at *A*, near each end, the object being to use the indicator on a flat surface when testing the spindle for parallelism with the V's, and on a cylindrical surface when testing the spindle taper hole for concentricity. The two squares are integral with a sleeve that can be turned independently of the bar, and in this way one plane surface can be set at a mean between the "high" and "low" point on the bar. This adjustment is obviously necessary, since the bar is particularly liable to run out at its free end, due to a number of conflicting elements, the error in any one of which may be infinitesimal. When using the plane surfaces, one of these is always trued up with the square *B*, as shown in the engraving.

The reason for providing a plane surface on which to indicate is this: Suppose, for example, that we are testing the spindle for alignment sideways, and further that the axis of the spindle actually is

parallel sideways with the bed, but that the axis does not lie in a horizontal plane, it being high on the front end, say 0.005 inch in the length of the test bar. Then in indicating on the older type of bar with cylindrical collars, the line of motion of the indicator point in traveling from one collar to the other is not parallel with the axis of the test bar and therefore the readings are false. Now, with the form of bar having plane surfaces, assuming the conditions to be the same as regards the alignment of the spindle, the reading will show that the alignment is perfect sideways, because the indicator point is moving on a plane surface.

Referring again to Fig. 9, the fixture *C* is guided on the V tracks of the bed and is constructed so that it is adjustable for holding a Starret indicator *D* either on the side or top of the bar as the case may require Having explained the use of the tools and fixtures, the method

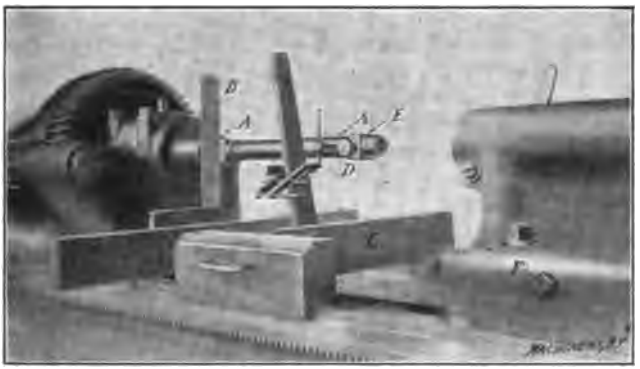

Fig. 9. Special Form of Test Bar for Aligning Head- and Tail-stock. Plane Surfaces are used for Testing Parallelism, and Cylindrical Surfaces for Testing Concentricity

of "lining up" the head-stock and tail-stock, both with reference to the V's and to each other, is to place them on the bed and approximately set the head-stock true sideways by inserting keys in the keyways planed in the head-stock and bed for this purpose.

With the clamping bolts tightened lightly (the bolts have 1/16-inch clearance), the head-stock spindle taper hole is first tested for concentricity by indicating on the cylindrical surface *E* while slowly rotating the spindle. Then with the squares *A* set as previously explained, the head-stock is moved around by knocking it with a babbitt hammer until the reading on both surfaces is the same. The bar is then moved over into the tail-stock spindle hole, and after the set-over screw *F* is adjusted so as to bring this spindle in line with that in the head-stock (the reading being the same as before) the tail-stock spindle is tested for alignment sideways. Now the indicator is set on top of the bar, with the latter turned so as to use the same surface, and then the tail-stock spindle is tested for alignment in a horizontal plane, after which the bar is again set into the head-stock spindle hole and that spindle tested both with reference to the V's and to the tail-stock spindle. It

is understood, of course, that if any errors are discovered which exceed the allowable limits of variation, the part at fault is either filed and scraped to bring it true, or machined, if the circumstances warrant.

Turning again to the lathe bed, we will assume that the head-stock is lined up as just described, and the clamping bolts are tightened down hard. The taper dowel pin holes are then drilled, reamed, and the pins driven in, care being exercised to see that the pins are a good fit. Next the faceplate is screwed on, ready to be turned off.

Lining Up the Lead-screw Boxes

As was previously stated, work has been progressing on the lead-screw boxes and other minor details. For the purpose of lining up the boxes and also to test the alignment of the lead-screw bearings in the apron, a short arbor is used that represents the lead-screw. First the apron is tested, and then the lead-screw boxes are bolted onto the bed and lined up with the apron. Sometimes it is necessary to file the apron seats or adjust the boxes to bring them into proper alignment; but with careful planing and thorough inspection of the parts, this should not be required. Two special gages are used to facilitate the aligning; one gage reaches down from the flat track on top of the bed for horizontal measurements, while another is held against the side of the bed just below the V to test sideways. Both gages are provided with micrometer points to enable the accurate measurement of error.

Referring to Fig. 1, the head-end lead-screw box is set longitudinally when the change gear sweep is in place, so as to line the box with reference to the sweep bearing on the end of the bed. When properly set, the boxes are drilled and reamed for the taper dowel pins; then the lead-screw is put in place, its checknuts screwed on, and the gears on the sweep brought into proper mesh.

The Finishing Operations and Inspection

With the cone belted up to a countershaft or other source of power, the bearings are thoroughly oiled, and the lathe is run idle for a while preparatory to turning off the face-plate. The V's on the bed and bearings on top of the carriage are now spotted with a scraper, while all other finished surfaces receive their final polishing. The centers and their respective holes in the spindles were fitted to male and female gages during the machining process, so that now it is only necessary to place the centers in position. Clamping on the center-rest is the final assembling operation.

All machines are more or less defective, as it is practically impossible to make anything absolutely perfect. Knowing this, the builder establishes a limit within which the error will not materially affect the working of the machine, and furnishes the inspector with a list of allowable limits.

The inspection is carried on as the work proceeds, so that no part is neglected, and no defective material or faulty workmanship is allowed to pass. Gearing of all kinds is inspected and tested for alignment and smoothness of operation. The fits of all wearing surfaces are tested, as well as the fit of the various screws and binding and

clamping fixtures. All information obtained from the inspection is entered on a printed form. Each machine is given a serial number, and the reports are filed in the office, so that in case of any trouble arising or any repairs being required for a given lathe, an exact record of its condition when it left the shop is available.

After truing up the face-plate, it is tested by means of a straightedge and cigarette paper, this kind of paper being the best for the purpose. The spindle is tested for end motion when running, by application of the Starrett indicator to the face of the spindle nose. To prove the alignment of the head spindle with the shears of the lathe and the alignment of the taper hole with the spindle under actual working conditions, a steel test bar is provided which fits the taper hole and projects 18 inches from the spindle. This bar carries three cast-iron collars, placed one at each end and one in the middle, from which all measurements are taken. A light cut is taken across these collars with a keen diamond-point tool, and the collars are then measured with a micrometer. As it is desirable when boring a hole, to have the taper, if any, large toward the front end, the front end of the headstock was purposely set slightly toward the rear of the bed so that the outer collar should be found 0.0005 inch larger than the collar next the spindle. The alignment of the spindle in the vertical plane is again tested by attaching the indicator to the tool-post and traversing the carriage along its ways with the contact point of the indicator pressing against the top surface of the collars.

In testing the alignment of the taper hole with the spindle itself, after the collars have been turned off, the test bar is removed, turned half way round and replaced in the spindle; the indicator is then put in the tool-post in place of the turning tool, and with the contact point on the center line, the indicator is traversed past the collars, the variation in readings showing twice the error in the alignment of the taper. The alignment of the tail-stock spindle is now tested, the method being the same as in the previous instance.

CHAPTER II

ASSEMBLING A MOTOR-DRIVEN PLANER*

In planer erection, the principal points to be observed are that the housings must be parallel with each other and square with the bed; accuracy is essential in the fit of all sliding members and in the truth of all plane bearing surfaces; the gears should mesh properly and run smoothly; and the system must be such as to permit the various parts to be easily and quickly assembled, and avoid the necessity of fitting the members together for the laying-out operations. This, of course, presupposes the employment of jigs and gages, but, owing to the fact that planers of the 48-inch size and upwards are seldom built in large numbers at a time, and further, that there are many different types of drive, it is impracticable to indulge very freely in the use of elaborate jigs for duplicating the larger parts in the larger sizes. However, many of the members used in the construction of planers are common to several different sizes and different types of drive, so that with a few very simple jigs and gages, the standard members can be made interchangeable, and in this way much expensive handling in laying-out, and the consequent lost time, is avoided.

This chapter will deal principally with the erecting process on the bed, since the methods and processes employed in assembling the smaller units do not differ greatly from the practice used in assembling those of other machine tools. All the principles involved in the erection of a small planer are encountered in the case of a large machine, and many other complicating factors are added; hence, the erection of a planer of the latter class will be described in detail. For this purpose a 48-inch motor-driven planer is selected, the general features of which are apparent from a study of the half-tone Fig. 10.

As the machining processes are so intimately correlated with those of assembling, and as the methods employed in the latter are controlled to a great extent by the former, a brief description of the points to be observed in machining, together with the gages used for testing the larger members, will be illustrated and described. Referring to Fig. 11, *A* indicates a gage for testing the V-surfaces on both the bed and table, it being shown in position on the latter. The surfaces *B*, which support the gage, are finished first, and in this way the gage is always kept in a horizontal plane and both tracks are the same width, so that when the table is placed in position on the bed, the top of the table will be square with the housings. Another advantage of this gage over the usual form having a bearing on both sides of the V, is that only two parallel surfaces are finished and tested at a time, which often saves changing the planing tools and resetting the tool-heads. The gage is squared by trying a 0.001-inch feeler on both sides of the gage at *C* and C_1. To determine the width of the

* MACHINERY, December, 1909, and January, 1910.

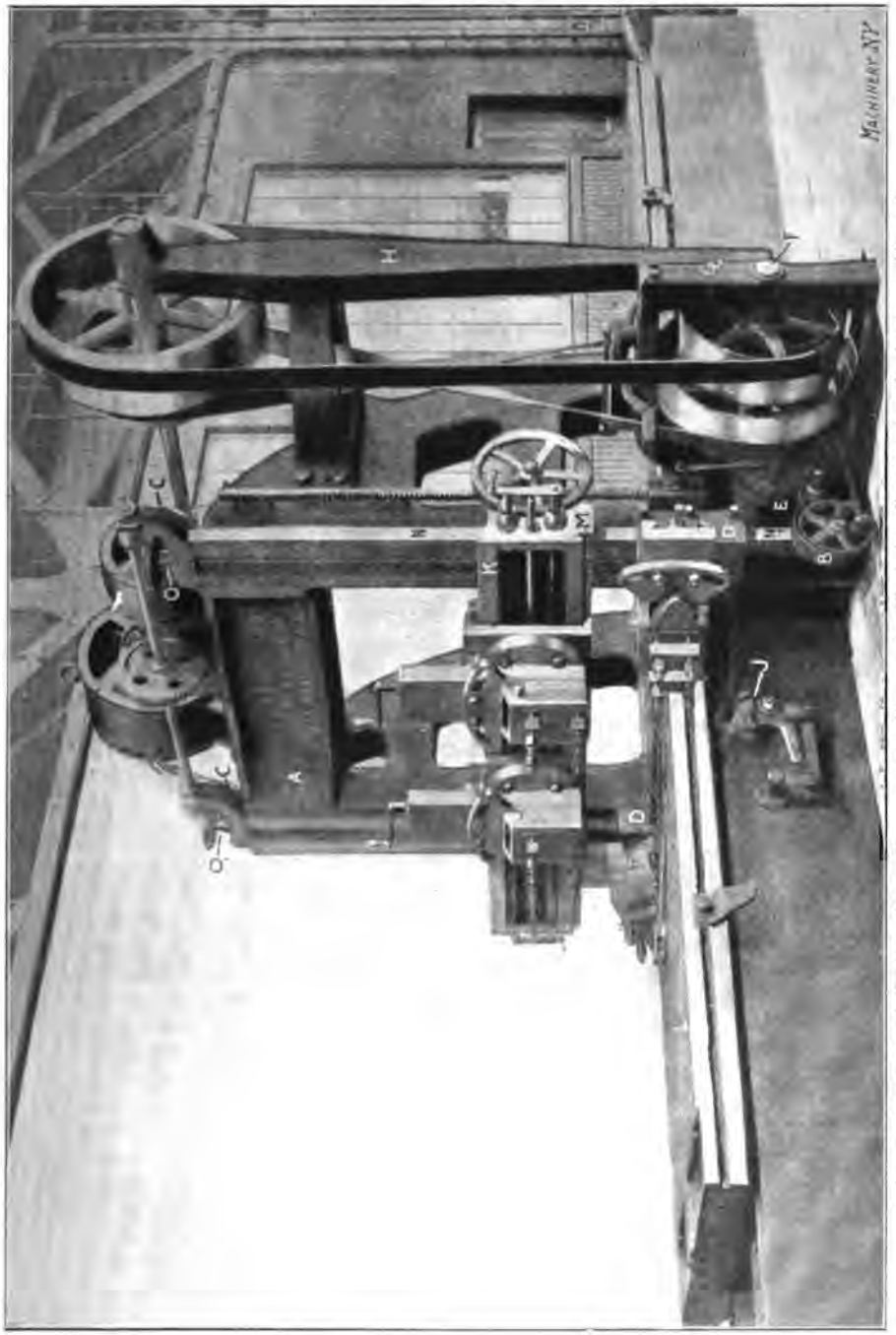

Fig. 10. Forty-eight-inch Motor-driven Planer, used as Example for Illustrating Principles involved in Assembling Planers

V-tracks on the bed and table, measurements are taken at D and D_1, respectively.

The gage just described is not adapted for measuring the rack seat, however, and, therefore, another gage is provided which fits both sides of the V's, and is represented by the dotted lines. This gage carries a slide E which measures the rack seat. At F is shown a sheet-iron support which fits either gage and prevents it from tipping over.

In the same illustration, at G, is shown the method of testing the table on surfaces H and H_1, which have a clearance of 0.005 inch between corresponding surfaces on the bed. As will be seen, the cast-iron gage block I fits the V on the table and is provided with two surfaces, one, J, for setting the planer tool, and another, K, for testing surface H after the finishing cut is taken. To the right, at L, is shown another cast-iron gage, this being used for setting the tools and testing the surfaces M and N; at L_1 the gage is shown in position in the V-track of the bed. As will be pointed out later, the object of finishing the surface N last is to provide a locating surface for the jig for boring the bed. In this way, the rack gear shaft hole is bored the correct distance from the V-tracks, so that when the table is in position, the table rack will mesh properly with its gears. Length gages O, P, Q, and R are for testing the measurements indicated, the latter also being used for taking the length of the arch A, Fig. 10.

It is essential, of course, that the housing cheeks on the bed be perfectly square with the V-tracks and parallel with each other. To accomplish this, the sweep S, carrying the Starrett indicator T, is used in connection with the straight-edge U, which reaches across the bed and extends a sufficient amount beyond one side to accommodate the swing of the indicator. By this means very accurate results are obtained. The operator holds the bar V in contact with the bed, and the flanged bearing W, being of ample diameter and ground true with the bar, keeps the bar in a vertical plane.

Boring and Drilling the Bed

The bed, having passed inspection with regard to the accuracy of the planing operations, is now sent to the horizontal boring and drilling machine where all the boring, drilling, and tapping operations are completed; one setting only is required, as the machine is provided with two separate columns carrying spindle heads, both working on the sides of the bed simultaneously. In the line-engraving Fig. 13 the bed is seen resting on parallels A with the jig B in position ready for the operations just mentioned. As will be observed from the top view, the jig consists of three main castings C, D, and E, respectively, which are bolted to the three cast-iron tie bars F; this construction permits adjustment of members D and E to compensate for beds having different widths over the housing cheeks. The jig rests on the top of the bed, and is located endwise with reference to the jig members D and E matching the bed casting, so that when the housings, which have been drilled by a separate jig, are bolted onto the bed, the castings will match properly. Set-screws G square the jig with the bed by holding

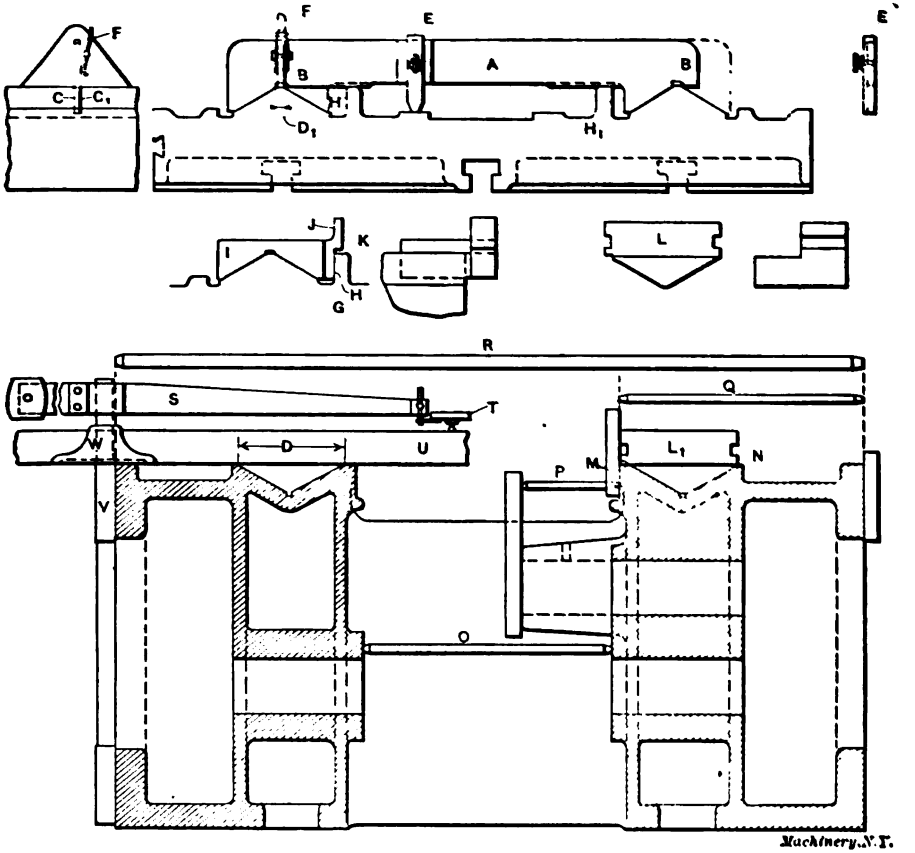

Fig. 11. Gages used for Testing Planing of Bed and Table

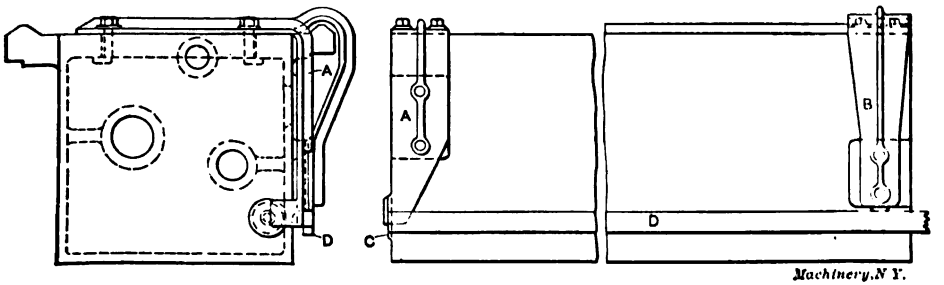

Fig. 12. Jigs used for Drilling Lead-screw Box Bolt Holes in the Bed

the jig against surface *H*. Suitable stops, straps and bolts secure the jig and bed to the base-plate during these operations.

For boring and reaming the shaft holes *I*, *J*, *K*, *L*, and *M*, two boring bars having suitable cutters and reamers are used.* The jig is provided with removable hardened steel drill bushings for the housing bolt holes *N*, the tapping being accomplished at the same setting of the spindle. Drill and reamer bushings are used at *O* and *P*, while a fixed drill bushing *Q* permits a small hole to be drilled for the taper dowel pin, ample stock being left for reaming after the housings are bolted on and properly located. After the boring and drilling operations are completed, the bed is moved over to the erecting foundation where the erecting process proper begins.

Drilling the Housings

In Fig 14, the front housing is shown at *A*, with jigs *B* and *C* in position for drilling the cheek bolt holes and the arch seat tap holes, respectively; the same jigs are used for the back housing, and jig *C* is also used for drilling the arch casting. The locating points and method of clamping the jigs are indicated in the engraving; as a matter of precaution, after the first hole is drilled in each case, a pin is inserted through the jig bushing into the drilled hole.

All drilling and tapping on this side of the housing being completed, jig *C* is removed, while *B* is secured by four bolts *D* having round heads fitting in place of the drill bushing collars, after which the housing is turned over in the position shown in Fig. 16. The drilling operations are performed on a cast-iron base plate provided with a portable motor-driven radial drill, this base also serving the purpose of a surface plate for laying out the work. It is important that the driving shaft bracket hole *A* and feed box shaft hole *C* line up nicely with corresponding holes in the bed, so that the shafts will run perfectly free when assembled. In order to accomplish this without having to assemble the members and housing on the bed, jig *B* is provided with flanged bearings, as at *D*, which support arbors located in the exact center position of the respective driving and feed shafts. The location of the bearings in this jig, and also of the bolt holes *E* is found by clamping the jig to the bed jig member *D*, Fig. 13, and boring the former in this position, so that the two jigs are identical with respect to the locating points and center distances of the holes.

Referring again to Fig. 16, driving shaft bracket *F* is first centered by the bushing *G* being pushed down into the hole; then the outboard bearing *H* and its member *I* are set approximately correct by means of shaft *J* and jig *K*, and held in this position by C-clamps, after which the truth of bearing *H* with respect to its being square is tested by means of sweep *L*, indicator *M* and the test block *N*, as shown in the engraving. When it is determined that bearing *H* is square and properly set, so that bushing *O* enters the hole in jig *K* without springing the shaft, all the clamping bolt holes are marked off,

* These boring bars are similar to those shown in Figs. 137 and 142, page 21, of MACHINERY'S Reference Series No. 43, Jigs and Fixtures, except that in the present case a middle support enables each bar to carry two cutters and two reamers.

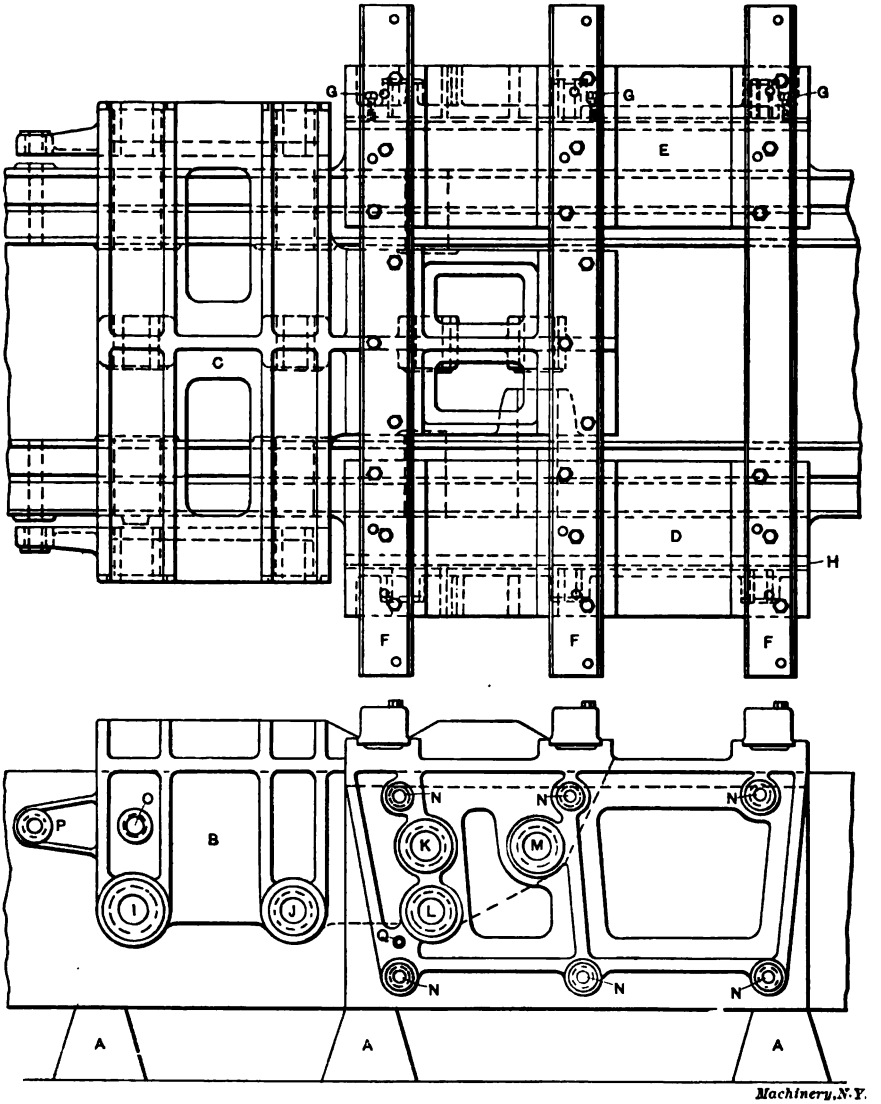

Fig. 18. Combination Boring and Drilling Jig in Position on the Bed

the brackets removed, and the holes drilled and tapped; then the brackets are bolted on, reset in the same manner, and the dowel pins fitted. In setting and testing these bearing brackets, particular care is exercised to insure the accuracy of the work, thereby saving much time when assembling the parts. As was stated at the outset, the fact that these driving works gener-

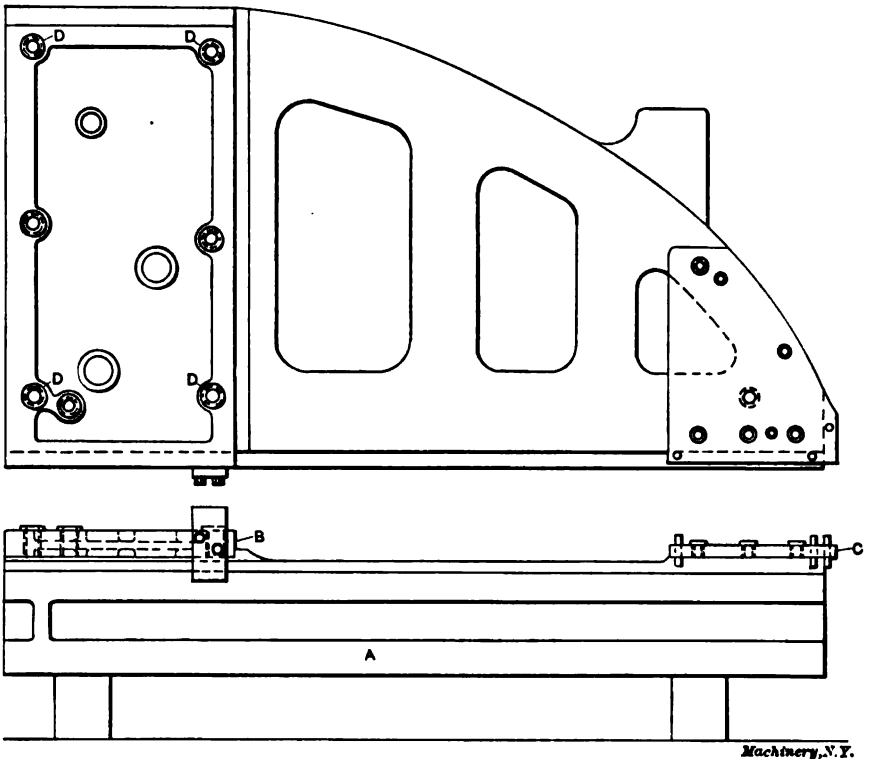

Fig. 14. Front Housing with Jigs in Position for Drilling Clamping Bolt Holes. Same Jigs are used for Similar Operations on the Back Housing

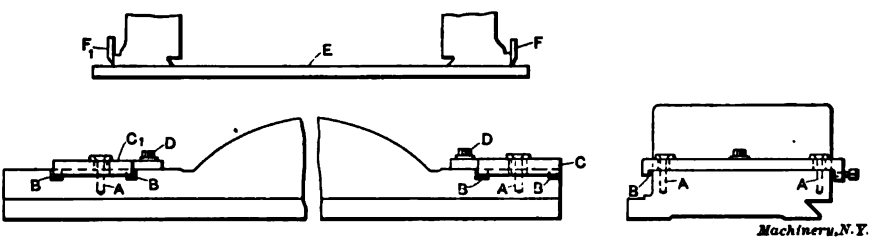

Fig. 15. Jigs for Drilling Stud Holes in Back of Cross-rail. Setting of Jig C1 endwise is accomplished by transferring Measurement from Housings by Means of Wooden Straightedge E

ally are of a special nature, is the reason why jigs are not provided for each individual member.

The cam operating lever bracket *P* is marked off after being set lengthwise to the correct dimension *Q*, and sidewise so that the center line of its shaft will coincide with a line laid off on the housing the right distance

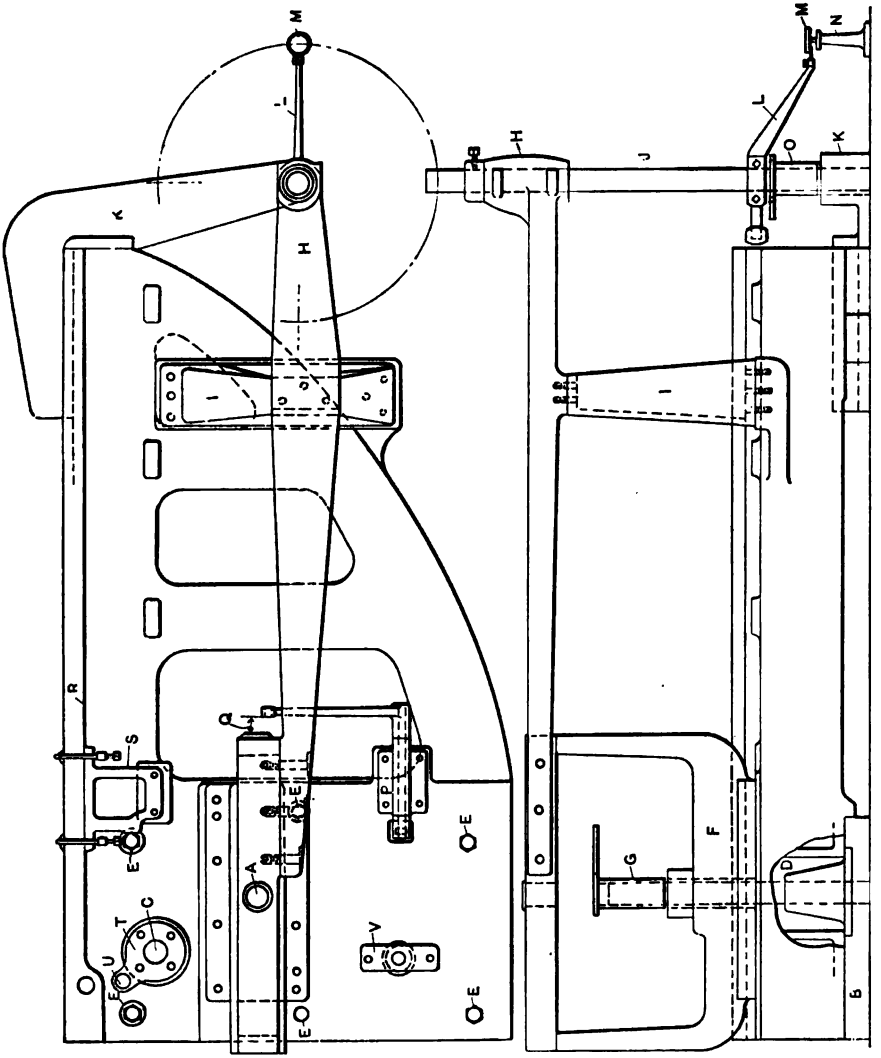

Fig. 16. Method of Setting and Laying out Holes for the Driving and Feed Members on the Front Housing

from surface *R*. A simple jig for drilling the feed rack casing holes is shown at *S*, the method of locating and clamping it being immediately apparent. Jig *T* is for drilling the feed-box clamping bolts holes; the jig consists of a flat plate centered by means of an arbor the same as at *D*, and located by a pin fitting into housing dowel pin hole *U*. A jig of similar construction and cen-

tered in the same manner, is illustrated at *V;* this jig drills the clamping bolt holes for a bracket carrying the side-head feed shaft. Simple jigs, not shown, are provided for drilling for the feed bracket *B* and elevating screw brackets *C*, Fig. 10, these two operations being performed on a horizontal drill. This completes the drilling on the front housing, and after the necessary drilling is performed on the back housing, using the same jigs as previously explained, the housings are tested to determine the accuracy of the planing.

Testing the Housings

One of the essential requirements of a first-class planer is that it must produce accurate work when using the side-heads, and this means that the ways on the housings must be true and parallel. When making this test, as shown in Fig. 17, the housings occupy the same position as when assembled on their bed, and it is at once apparent that whether or not the front faces stand perfectly plumb, is a matter of little consequence, so long as the faces lie in the same plane. With respect to the side faces and angles, however, the conditions are different; these must be square with the bed. Casting *A* which corresponds to the cheeks on the planer bed is bolted to a suitable concrete foundation and carries two V-blocks *B*, forming bearings for the sweep bar *C* which in turn supports sweep *D* and indicator *E*. The bar is held in the V-blocks by straps *F* and wooden blocks *G*, while collar *H* and its thrust bearing *I* take up all lateral motion. The construction of sweep proper, *D*, is such that clamp *J*, carrying the indicator, may be secured in any position of its travel between the two seamless steel tubes *K*, which enables readings to be taken at various points.

After being bolted onto the jig, the housings are located against strap *L* by means of screws as at *M*. It is desirable that the front faces show about 0.001 inch low at their outer edges, as at *N*, so that when the cross-rail is in position it will surely have a bearing across the entire face of each housing. Measurements are also taken across *O* at various heights, and between the arch seats *P*, to determine the parallelism of these surfaces. It should be explained that, in the side view, the front housing only is shown for the purpose of more clearly illustrating the sweep bearings. The housings having passed inspection in this test, are next turned face uppermost in a suitable pit for convenience in scraping on the side-head shoes *D*, Fig. 10, after which the housings are ready to be placed in position on the bed.

As has already been stated, the principal points to be observed in planer erection are: housings parallel with each other and square with the bed; accurate fit of all sliding members and truth of all plane bearing surfaces; proper mesh and smooth working of gears, and a system that permits the various parts to be easily and quickly assembled, and avoids the necessity of fitting the members together for the laying-out operations. We have now completed the boring and drilling of the bed, the drilling of the housings, and the testing of the housings. We will now take up the laying out of the arch bars, the assembling operations on the bed, the setting of the housings, the assembling of

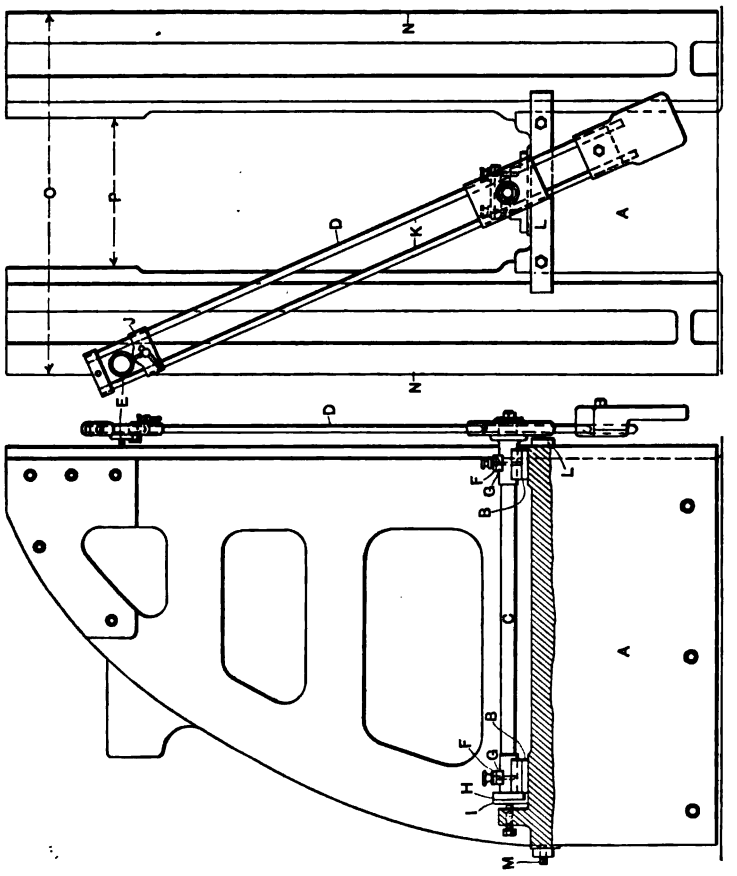

Fig. 17. Special Fixture used for Testing Alignment of Housing Faces, provided with Sweep for Carrying Starrett Indicator

the driving, feed and arch members, the laying out and setting of the cross-rail, and the final testing and inspection.

Laying Out the Arch Members

The first drilling operation on the arch is for the housing bolts, the jig for this being shown at *C*, Fig. 14; then the arch is set under the drill in its normal position and the brackets and motors are located for marking off the bolt holes, as illustrated in Fig. 18. When these holes have been drilled and tapped, the arch members are bolted in place for drilling the dowel pin holes, this time more care being exercised in the setting. This is another instance where the varying character of the parts precludes the use of drill jigs, and a method of laying out the work must be resorted to. For convenience in obtaining

accurate measurements, and to facilitate the work, a pair of adjustable angle-plates are used, as shown at *A*, the idea being to use an arbor in the bracket hole *B* and to provide a positive locating surface at each end, against which the arbor just touches.

The location endwise not being as particular, a line is scribed on the arch the correct distance from end *C*, and the bracket, with a scale held against the end, is set so that the edge of the scale coincides with the line just mentioned. As will be seen from the detail view, the angle-plate is adjustable on its base *D*, and may be turned end for end and clamped in any position as the case may require, fine adjustment being made by the screw *E*. Fastened to base plate *D* is a scale, while attached to angle-plate *F* is a vernier, this combination enabling very accurate settings; all readings are taken from the lip *G* to surface *H*, and it is necessary, of course, to add half the diameter of the shaft to

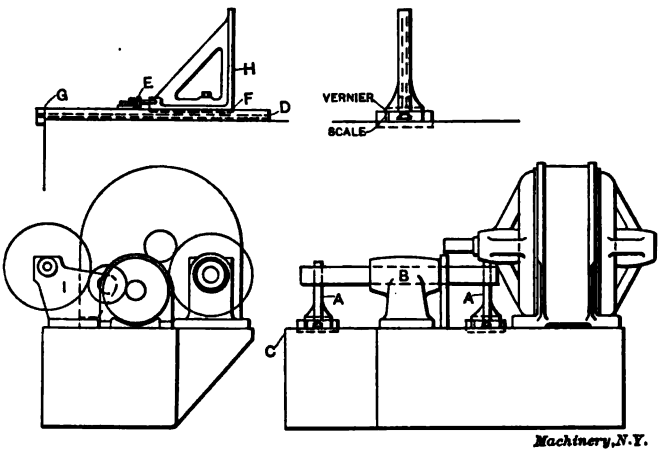

Fig. 18. Arch with Bracket Members and Motor in Position for Laying Out

obtain the center distance. Bracket *I*, for the top elevating shaft, is set in the same manner, except that the angle-plates are reversed on account of the bracket being so close to the edge of the arch. With both brackets bolted fast and pinned, and their gears in place supported on short arbors, the motors are set so that their pinions mesh properly with the respective gears; then the motor clamping bolt holes are marked off, drilled and tapped, and the motors reset for pinning. In case the design is such that the entire top surface of the arch casting is not planed, *i. e.*, where finished seats are provided for the brackets and motors, additional spots are required for the angle plates. These spots are conveniently located on the casting and are finish planed with the other seats.

Assembling Operations on the Bed

The first assembling operations proper on the bed consist of drilling the various set-screw and oil pipe holes; drilling and fitting the track oiling device, a drill jig for which is shown in Fig. 19, and assembling

the rack gear, its shaft, and the two intermediate compound gears and shafts. These operations, together with placing the housings on the bed, are done before the leveling operation, as otherwise the consequent hammering and additional weight of the housings might throw the bed out of level.

During erection, the bed is supported on cast-iron parallel blocks placed about six feet apart along the whole length of the bed and also under the housings. Planed cast-iron wedges, having screw adjustment, are placed between the parallel blocks and the bed, thus enabling very accurate leveling to be accomplished. The arrangement of all the blocking is such that none of it will interfere with the driving and feed mechanism during erection, and as these details vary in different machines, the blocking must be arranged to suit each machine.

Several methods may be followed in leveling a planer bed, any one of which will give good results if the work is carefully done. The

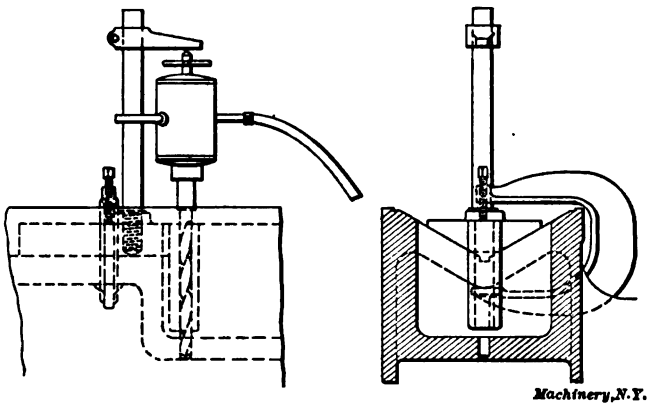

Fig 19. Combination Drill Jig and "Old Man" for Drilling Hole in Oil Pockets for Oiling Device. Jig insures Hole being drilled in Center of Way

prime requisites are, of course, a first-class, sensitive, spirit-level—one at least 18 inches long—and an accurate parallel that will reach across both tracks. It is obvious that since the tracks in a new bed are not worn, just as good results are obtained in leveling by using the top surface on the tracks as by using either V-shaped parallels or cylindrical pieces in the ways. The leveling is done as follows: The level is used on the top surface of one track, and that side of the bed is carefully leveled by moving the instrument short distances at a time, over the entire length. Then, by placing the level on the parallel, the bed is leveled crosswise; the operation of first leveling one side and then cross-leveling to the other is repeated several times, or at least until no further errors can be detected.

Setting the Housings

Fig. 20 is a top view of the planer, and shows the general method of setting the housings; the operation involves the alignment of the driving shaft bearing in bracket *A* with that in the bed at *B*, and

also includes bringing the faces of the housings into the same plane. With the housings bolted to the bed only sufficiently tight to hold them in place, and with driving shaft bracket *A* bolted and pinned fast to the front housing *C*, an arbor *D* is used as indicated. This arbor is ground true and is a wringing fit in the bed at *B*, and, being of smaller diameter where it passes through bracket *A*, permits it to be easily introduced into the bed bearing even though the bracket hole is out of alignment. This condition is possible, of course, since the clamping bolts *E* have ⅛ inch clearance in the housings. Now, with bushing *F* in position to enter hole *G*, the front housing is driven with a babbitt hammer, either forward or backward as the case may require, until the bushing enters the hole freely without springing the arbor.

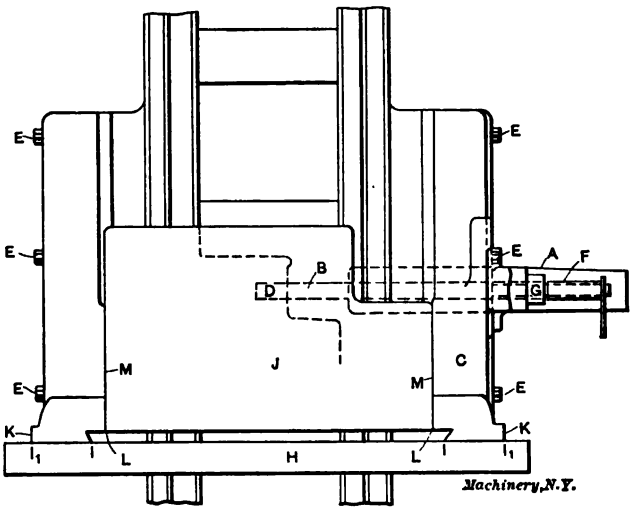

Fig. 20. Method of Setting the Housings. First the Front Housing is set for Alignment of Driving Shaft Bracket A; then the Back Housing is brought into the Same Plane by means of Straightedge H

To set the back housing, a straightedge is laid across the bed as shown at *H*, and narrow strips of tissue paper are introduced at *I* and I_1; then, by moving the back housing until papers *I* are tight and I_1 can just be moved, it is determined that both housings are in proper alignment. The fact that the outside papers are slightly loose is due to conditions already stated. After reaming the housing dowel pin holes by means of an air drill, and driving in the pins, measurement is taken for arch casting *J*, and the housings are calipered over surfaces *K* just above the bed, and at the top, to test their parallelism.

While an attempt is made at interchangeability with respect to the length of the arch member, it sometimes happens that certain elements make it necessary to slightly deviate from the standard measurement. For instance, the above test may show the measurement over *K* to be from 0.002 to 0.003 inch wide or narrow at the top, in which

case the housings are made parallel by means of a jack-screw, or tie-rod, as the case may require, and then the arch is machined to suit. The arch is now bolted in place, and set to match the housings at *L* and *M*, after which it is pinned.

Assembling the Driving, Feed and Arch Members

The cross-rail, side-saddles, and the various driving and feed units are assembled in a department separate from the erecting department, and these parts usually are duplicated in quantities and come from the store-room to the erectors completely finished. In all cases where possible in assembling these units, standardization is provided for, and in this way much time is saved by the erectors avoiding unnecessary adjustments.

Referring back to Fig. 10, the feed box *E* is next bolted in place, and after assembling the driving shaft *F* with its members, and bolting on the bracket member *G*, the outboard bearing *H* is bolted in position. The arch bearing for the fly-wheel shaft *I* already being secured in place, this shaft is red-leaded and tried in its bearings to test their alignment. When proper care is exercised in the aligning operations, very little scraping is necessary on these bearings.

While work is proceeding in assembling the top works, elevating screws, and motors, other erectors are busy with the side-heads *D*, rocker mechanism *J*, and the feed mechanism for the side-heads and cross-rail; each unit is assembled in logical order, and as many operations as possible are carried on simultaneously. The planer is now ready for the cross-rail *K* and table *L*, preliminary work on these members being completed far enough ahead so as to cause no delay at this point.

The operations on the table consist of drilling and reaming the stop-pin holes, drilling and bolting on the rack, and rough scraping the tracks; the oil grooves were cut in the machining process. A large motor-driven multi-spindle drill is used for drilling and reaming the stop-pin holes. This machine carries sixteen spindles, arranged in two rows; one row of spindles carries the drills, and the other the combination mills and countersinks. After the first row of holes is drilled and the table is indexed along the space of one row, the combination mills and countersinks are inserted, and the sixteen tools are used simultaneously, thus producing very rapid work. The table is supported on a special truck running on a track between the drill uprights, and a suitable mechanism for moving and indexing the table completes the equipment. Previous to placing the table on the bed, the ways on the latter are also rough scraped, and then the bearing surfaces receive a coat of red lead which serves the double purpose of marking material and lubricant.

Laying Out and Setting the Cross-rail

The stud holes *A* for the cross-rail gibs are drilled in the manner shown in Fig. 15. As will be seen, spots are planed off at *B* which serve to square jigs *C* and C_1, and the holes for the elevating screw nuts are utilized for clamping the jigs by means of bolts *D*. Endwise

location of jig C is determined by matching the end of the cross-rail as shown; then jig C_1 is set by transferring the measurement from the housings by means of the wooden straightedge E. A flat scriber, shown at F and F_1, is used to mark lines on the straightedge which is chalked for this purpose, and when corresponding lines on the jigs coincide with those on the straightedge, jig C_1 is properly set.

When the studs are screwed in place and the back surface of the cross-rail is scraped, the cross-rail is placed in position on the planer and clamped by its gibs. Squaring the cross-rail with the housings is accomplished by holding the bar of a sweep in the angle M, Fig. 10, and applying an indicator to the front housing at N and N_1. The low end of the cross-rail is raised a sufficient amount by either moving the teeth in bevel gear O or O_1 (Fig. 10), as the case may require, in relation to its pinion, or by adjusting one of the nuts on the gear end of the elevating screws, final adjustment being obtained by the

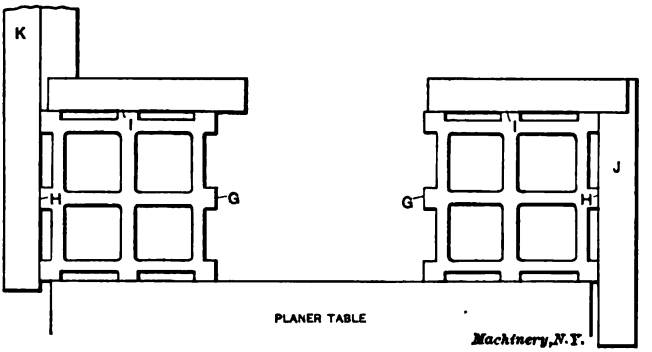

Fig. 21. Method of Testing Accuracy of "Planing Square" when using the Side-heads

latter method. It is always better to raise the low end rather than lower the high end of the cross-rail, on account of the fact that this will take up any lost motion or backlash between the nuts, the feed-screws, and the housings. As the studs have 1/16 inch clearance in the gib, it is necessary to pin the latter after setting the cross-rail.

Final Test and Inspection

With the motors wired up, the belts in place, and the machine thoroughly oiled, the driving works are run for a while before moving the table into mesh with its rack gear, the idea being to prevent possible heating of the bearings by running without load. Next the table is brought into mesh and the bed is again carefully leveled in the same manner as before. When this is accomplished, the ways and tracks are scraped to a bearing, after which the ways are oiled and one or more cuts taken across the table to true it up for the purpose of testing the planer. A straightedge tried on the table crosswise, lengthwise, and across corners, is used to test the truth of the planing.

The side-heads are next tested for "planing square" by the method illustrated in Fig. 21. Two cast iron parallels G are clamped one on

each side of the table as shown, and then light cuts are taken down faces *H* with tools in the side-heads. Now, with the faces *H* clamped to the table, cuts are taken down faces *I*, after which the parallels are turned back to their original positions and a square tried as at *J*. To "prove" the square, it is used in connection with a straightedge (on the same parallel) as at *K*, any error detected between the blade of square and the straightedge showing double the amount of actual error.

The accuracy of setting the cross-rail is now determined by taking a light cut across faces *I*, using a tool in one of the cross-rail heads, and testing with the square and straightedge as in the previous case. The object in making these tests is a precautionary measure, for by testing the planer under actual working conditions, the accuracy of the tests made during erection are thus proved.

Final inspection includes running the cross-rail to the top of the housings to test the elevating mechanism and ascertain the fact that there is clearance between the cross-rail and arch. All gearing is tested for quiet and smooth running; the fits of all bearing surfaces are inspected; the slides and saddles are run by hand to test the parallelism of their ways and also the ease with which the slides operate, after which the power feed is applied and tested in various ways; the balance of the driving motor armature, and of the fly-wheels and pulleys also, receives careful inspection; in fact, no part is neglected and all errors must be within allowable limits of variation. All tests are made under the personal supervision of an inspector, who enters all data on a form prepared for the purpose, and this report bears the serial number of the planer, and is filed away for future reference.

As opportunity offers during erection, the filling, rubbing down, and priming has progressed, so that after inspection, all that remains to be done is to give the bright parts their final polish, and apply the last coat of paint.

CHAPTER III

LAYING-OUT AND ALIGNING OPERATIONS*

In general, laying out is the process of placing such lines on castings, forgings, or partially finished surfaces, as will designate the exact location and nature of the operations specified on the drawing; an aligning operation, as its name implies, consists in lining-up a shaft bearing, bracket, or other similar machine element, in its proper place relative to other members. The first-named operation usually is associated with the process of machining, while the last-mentioned is generally included in the work of assembling. Laying-out and aligning operations may be divided into two parts; the preliminary and the final. The preliminary operation consists in approximately locating a machine element in place for the purpose of marking the clamping bolt holes on its supporting member; in the final alignment, the exact location is ascertained for the purpose of drilling the dowel pin holes, the work being held by its clamping bolts. Clearance in the bolt holes permits of this adjustment.

As the ultimate results obtained in assembling are controlled to a large extent by the accuracy of these operations, it is of the utmost importance that means be provided for insuring the refinement that the nature of the case demands. Jigs and fixtures have, of course, been a dominant factor in dispensing with much of the ingenuity and skill required in this work, but owing to special considerations a preclusion of these valuable adjuncts to manufacturing work may be advisable. In this case a simple gage or templet, or even a wooden jig provided with steel bushings, will greatly facilitate the operation of laying out or aligning, and, in fact, when proper care is exercised in using these comparatively crude devices, work may be produced on an interchangeable basis as good as with more expensive tools; although it is to be expected that more skilled labor will be required.

As regards the different methods of laying out and aligning, no definite rules can be given. The machinist must consider the means at hand and the nature of the job; he must then use his ingenuity and be guided by his practical experience. A few special cases are illustrated in the accompanying line-engravings; the methods and processes shown and the remarks made in regard to them are intended only as suggestions of how the work may be accomplished without the employment of drill jigs. It is not to be inferred that the way shown is, in each instance, the best method possible and the only one applicable. Circumstances alter cases; while the methods shown may be eminently suitable for one set of conditions, they may either be too refined or not refined enough for other requirements.

* MACHINERY, February and March, 1910.

Special Tools and Appliances

Aside from the more common laying-out tools such as the dividers, surface gage, steel scale, etc., there are a number of tools of a special form used for laying-out operations, some of which are shown in Fig. 22. The form of center punch shown at *A* will greatly facilitate marking off holes through brackets and templets, or in laying off pin holes for cams. It is necessary to provide a number of different sized center punches of this type, as the body of the punch must fit the

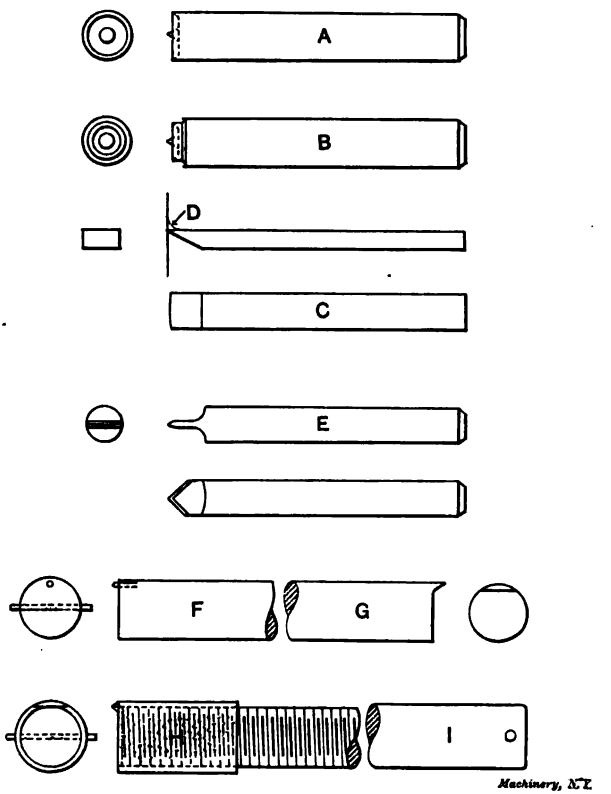

Fig. 22. Special Tools used in Laying-out Operations

clearance hole in the work. For obtaining a circle, the diameter of the tap drill, the punch or marker may take the form shown at *B*, while a combination of the two will provide a guard circle.

A flat scriber *C* is very useful for marking a line on a plane surface at right angles to another plane surface when the corner is rounded as shown at *D*. The form of marker illustrated at *E* is for giving permanence to lines intersecting on surfaces at right angles, as for instance, in marking the relative position of a gear on a shaft. At *F* is shown a special marker for laying out a circle, the center of which

must coincide with a hole already bored. The body of the marker fits the bored hole and a circle is scribed in the piece to be marked off by rotating the marker when the point is in contact with the work. Two methods of making the scribing point are clearly indicated in the engraving, the one shown at end *G* producing a circle the diameter of the body. In marking off a hole in alignment with a threaded hole, a bushing *H* having a scribing point is made to fit the threaded arbor *I*. This arbor fits the threaded hole, and the bushing is rotated to mark the circle.

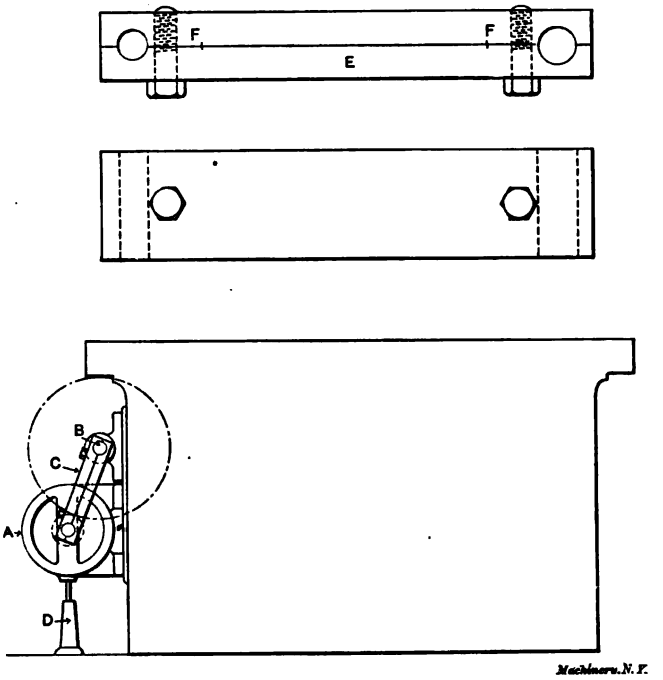

Fig. 23. Locating a Small Motor by the Use of a Link

One of the most convenient and accurate methods of locating gear centers is by the use of links. For drilling or boring operations the link may take the form of a casting provided with hardened steel bushings to guide the cutting tools. Again, a link may be used for cases similar to the one shown in Fig. 23, which illustrates the method of accurately setting a small motor *A* so that its pinion will mesh properly with a gear on shaft *B*. The work is accomplished as follows: With the link *C* and the motor in position as shown, the jackscrew *D* is adjusted until the motor frame just touches the finished seat on the bed. This adjustment is determined by means of tissue paper placed between the motor and bed, after which the bolt holes are marked off on the bed; the special marker *B*, Fig. 22, is used for

the purpose. The construction of the link is clearly shown at *E*, Fig. 23; this form, being made of two pieces bolted together, permits of ready application to a shaft supported between bearings, without removing the shaft. Such a case is frequently met with in applying a geared pump to a machine already built. For ordinary cases, however, the link may be made in one casting or forging, as the circumstances require, and provision for clamping may be made by sawing through the ends as far as indicated at *F*.

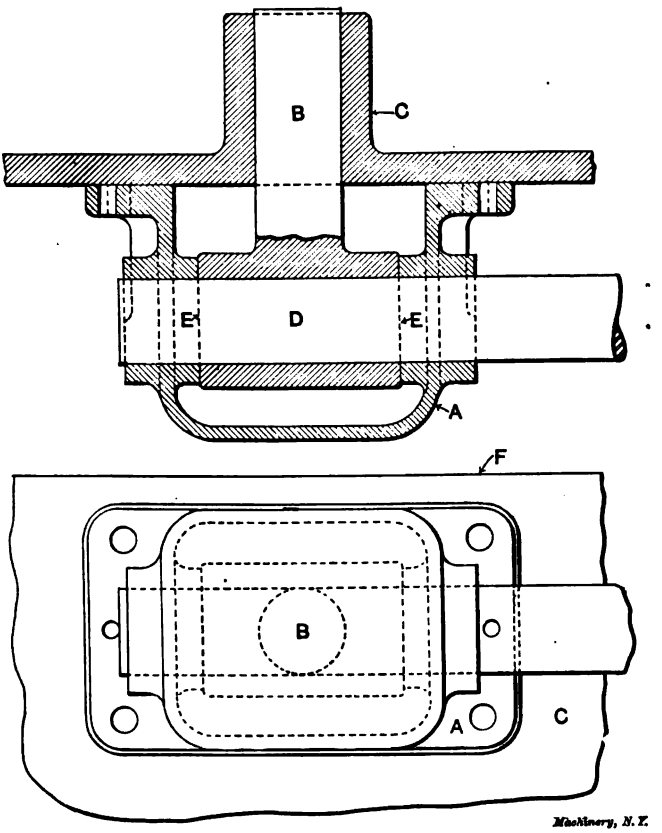

Fig. 24. T-jig for Locating a Bevel Gear Bracket

In Fig. 24 is shown a T-jig for locating a bearing bracket *A* relative to the hole *B* in the main casting *C*. The requirements are that the axes of hole *B* and shaft *D* must intersect, and the faces of hubs *E* must be equidistant from the axis of *B*. It is evident, however, that the T-jig will not take care of the alignment of the shaft *D* with reference to its being parallel with the surface *F*. This may be accomplished by measuring down from surface *F* with either a combination square or surface gage or, in case the adjacent bearing for shaft *D*

is already located, bracket *A* will find its own alignment by using this bearing to support the shaft.

The Use of Templets

When a number of pieces are to be made interchangeable without the use of jigs or fixtures, this can be accomplished by the employment of templets for laying out the work. While these devices greatly simplify laying-out and aligning operations, they are not intended for guiding the cutting tools. Templets are particularly well adapted for work

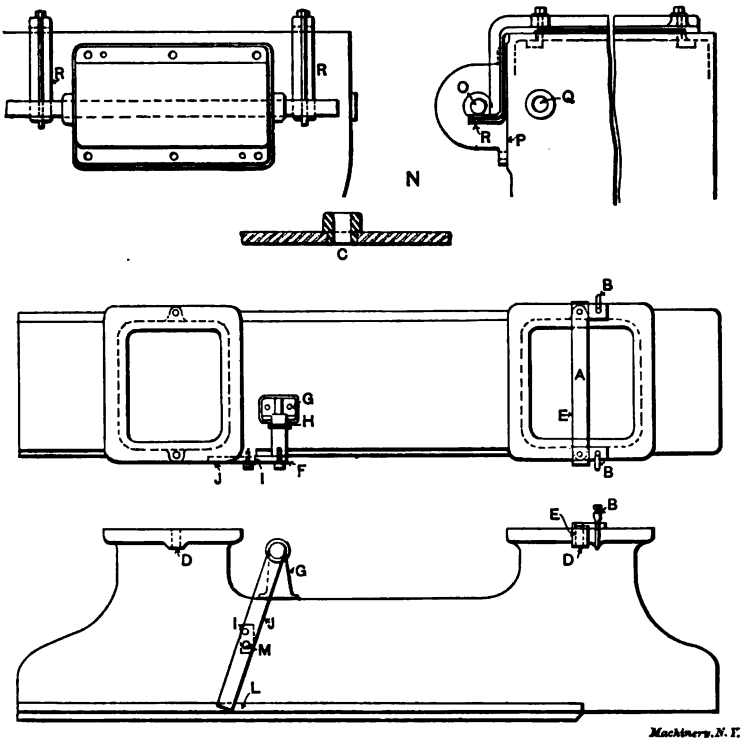

Fig. 25. Special Gages and Templets for Laying-out and Aligning Operations on a Turret Lathe Bed

where the holes to be laid out lie in the same horizontal plane, and owing to this condition, the templet usually takes the form of a flat plate of sheet iron, or a wooden piece, having the same general outline as the work to be laid out. Again, many irregular forms are drawn on work from accurately filed templets, after which permanence is given the lines by dotting them with prick-punch marks placed directly on the line.

In making a templet for the first-mentioned class of work, holes are drilled in the templet to conform to the drawing of the piece to be laid out. In use, the templet is laid on the work and is then clamped

to it by suitable and convenient means, so that its outline coincides with that of the work. The layout may be transferred to the work by means of a marker as already explained, or, in the case of comparatively large holes, an ordinary scriber is used to mark the circles, and after the templet is removed from the work, the center of each circle is laid out with dividers, permanence being given the lines by a prick punch. Witness circles are often placed on the work to make sure that the original lines were closely followed in drilling, *i. e.*, a circle is drawn in each case 1/32 inch larger in diameter than the one worked to; then, if the hole is correctly drilled, it will be concentric with this circle.

For a certain class of work where great accuracy is not required, templets may be made provided with hardened steel bushings for guiding the cutting tools independently of the skill of the operator, in which case, however, the templet takes the form of a jig. Owing to the lack of rigidity due to the thin material of which such jigs or templets are constructed, no attempt is made to provide clamping arrangements. The templet may be clamped to the work by means of ordinary C-clamps, or with machinists' clamps. Very frequently, however, it is desirable to provide locating points which may consist of pins extending from one or both sides of the templet, as the case may require, or the locating points may be formed by bending the edges of the metal to a right angle.

The application of a jig such as just described is illustrated in Fig. 25, which shows the method of drilling foundation bolt holes in a turret lathe bed, the holes being drilled from the bottom. As will be seen, the jig or templet *A* consists of three pieces of flat iron riveted together and clamped to the bed by means of clamps *B*. The method of inserting the drill bushings is shown in detail at *C*. To facilitate setting the jig with reference to the bosses *D* on the under side of the bed casting so that the holes when drilled will be concentric with these bosses, jig member *E* is bent to a right angle as each end so as to extend down the casting; the location is determined by matching these ears with the bosses on the bed.

In Fig. 26 is shown the application of sheet-iron templets for laying out cross-rail members for lathe planers. Templet *A* for swivel member *B* is located by the hub *C*, and is lined up to match the end *D*. A separate templet is provided for laying out the swivel clamp *E*; edge *F* of the templet is bent over to form a locating point. But one templet is required for laying out slide *G* and its clapper-box *H*. This is lined up on each member as shown. It is obvious that these templets are more advantageous than cast-iron jigs for this class of work, since very large and heavy jigs would be required, and furthermore, no great accuracy is necessary, as the bolt holes have 1/16 inch clearance.

As already stated, a very cheap and serviceable jig for certain classes of work can be constructed of wood. At *A*, Fig. 27, is shown a jig of this character for drilling the clamping bolt holes in an engine lathe head-stock—in this case for a 30-inch lathe. The jig is located by pin *B* and keys *C*, the latter fitting a keyway in the headstock; having these keys on both sides of the jig as shown at *D*, it is also used for drilling

the tap holes in the lathe bed, not shown. Steel lining bushings *E* are provided for the drill bushings. The jig and work are clamped to the drill press table by straps and bolts. The frame consists of four pieces of ash fastened at the corners with glue and wood screws, the joints being made as shown. Ash is the best wood for the purpose, since, if well seasoned, it is less likely to warp than any other, but where this wood is not available, maple is a good substitute.

A slightly more expensive, but more durable jig, for the same purpose is shown at *F* in the same engraving. This jig is made of flat

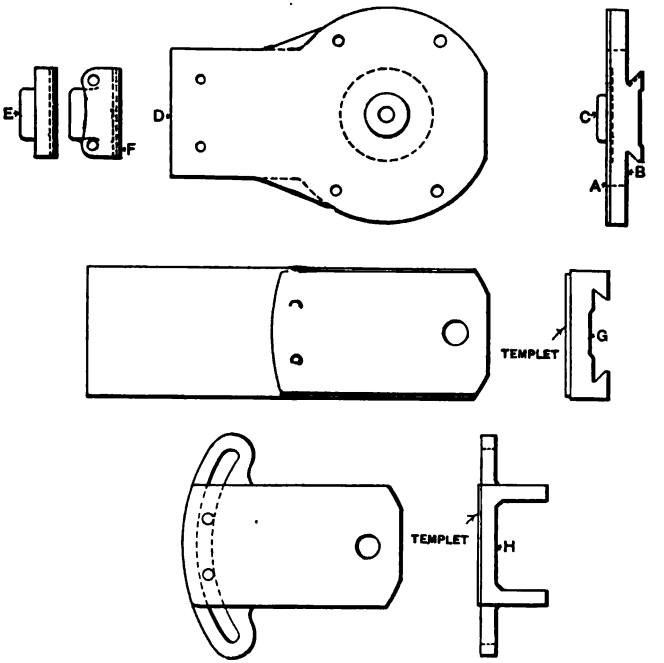

Fig. 26. Sheet-iron Templets for Laying out Planer Cross-rail Members

bar steel riveted together, and is of the same general construction as the wooden one.

Gages for Aligning Operations

A gage may briefly be defined as any standard of comparison; as here used, the term gage will have reference to special devices for aligning work without the employment of ordinary tools such as a combination square, surface gage, etc. Besides greatly facilitating aligning operations, the particular advantage of using gages is that the possibility of error due to carelessness in transferring scale measurements is avoided. It is assumed, however, that the gages here shown are intended only for duplicate work; it would not be economy to make gages for aligning only a few pieces.

Turning back to Fig. 25, *F* represents a simple gage for aligning bracket *G* on the bottom of a turret lathe bed. The requirements are that face *H* of the bracket must be a certain definite distance from seat *I* on the bed, but the alignment in a longitudinal direction is non-essential. The gage merely consists of two pieces; a straightedge *J*, planed only on one side and one end, and a gage which is fastened to the end of the straightedge as shown. As surface *L* on the bed lies in

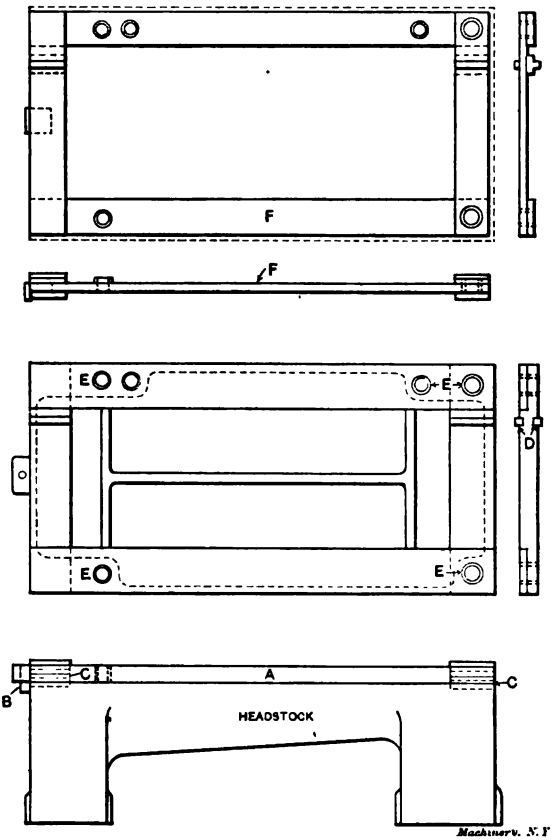

Fig. 27. Application of a Wooden Jig for Drilling a Lathe Head-stock. At F is shown a Similar Jig Constructed of Flat Bar Steel

the same plane with seat *I*, the straightedge is made long enough to reach this surface, thereby obtaining greater accuracy in the alignment. Bolt hole *M*, already tapped, is utilized for clamping the gage. In aligning the bracket, its face is brought into contact with the gage, and the bracket is then set longitudinally to match its seat on the bed.

Another gage, or more properly speaking, a pair of gages, for aligning a feed-box on the turret lathe bed shown in the lower part of the same engraving, is shown at *N*. The requirement of the present case

is simply that the feed-box shaft hole *O* be located a certain definite distance from the top of the bed; seat *P* on the bed takes care of the center distance from hole *Q*. It is obvious then, that the gage castings *R* should only provide a positive locating surface with reference to the top of the bed; this is accomplished in the manner shown. The location endwise is determined by scale measurements from the end of the bed.

An aligning operation on a vertical boring mill bed, and the gage

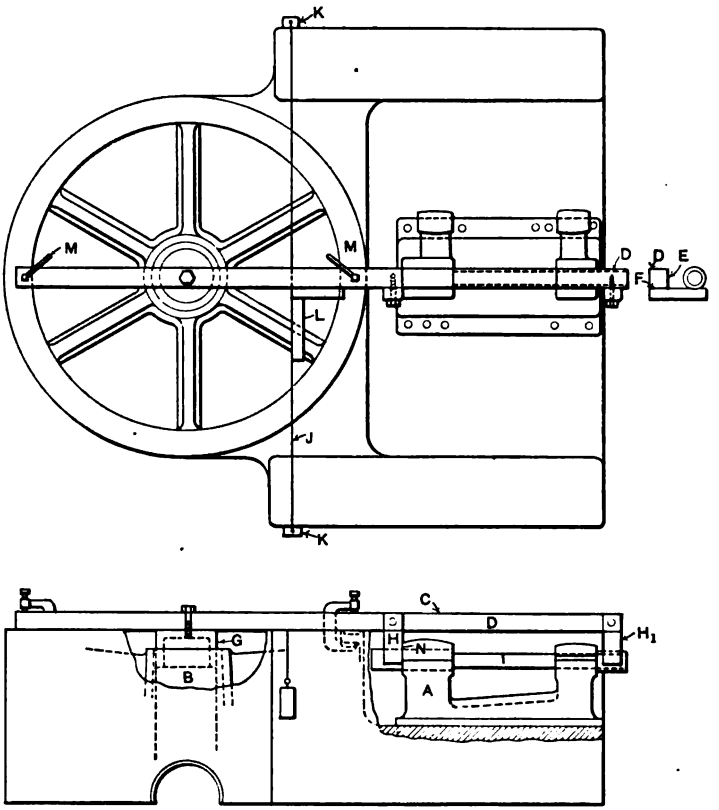

Fig. 28. Gage for Aligning the Driving Shaft Bracket on a Vertical Boring Mill of the Bevel Gear Driven Type

used, is illustrated in Fig. 28. This boring mill is of the bevel gear driven type, in which the pinion meshing into the table bevel gear is carried on the driving shaft in bracket *A*. The problem of aligning this driving shaft bracket with reference to the spindle hole *B* in the bed, is easily solved by using gage *C*. As will be seen, this gage consists of a bar *D* planed on two sides, *E* and *F*; a bushing *G* fitting the spindle hole; and two gage pieces *H* and H_1. A special arbor *I*, having both its ends ground to the same diameter, fits bracket *A*.

When in use, a line wire J is stretched across the bed by means of weights K. This wire lies in a small groove or mark planed in the bed for the double purpose of squaring the gage and setting the housings. Square L is used in setting the gage before it is clamped by means of clamps M, so that when the bed members are assembled, the driving shaft will be approximately square with the housing faces. With the gage in this position, bracket A is set so that its arbor just touches the gage blocks H and H_1. The location with reference to the distance from spindle hole B in the bed is determined by simply bringing the hub face N on bracket A into contact with the side of gage block H. After the operation of marking off the tap holes in the bed is accomplished, and the holes are drilled and tapped, bracket A is reset in the same manner and clamped by its bolts, for drilling and reaming the dowel pin holes.

Laying-out and Aligning Operations without the Use of Special Tools and Appliances

In the absence of special tools and appliances for laying-out and aligning operations, the principal points to be observed are the selection of a proper starting point from which to lay out all dimensions, the employment of efficient means to compensate for the deflection in horizontal aligning arbors when the bracket seats lie in a vertical plane, *i. e.*, when it is impracticable to place the bed of a machine in such a position that the bracket seats will lie in a horizontal plane and thus carry the bracket members unsupported; and the avoidance of assembling all the correlated members together for the laying-out operations.

The first two points brought out above are exemplified in the aligning operations on a vertical boring mill of the spur pinion driven type, which is illustrated in Fig. 29. The operations involved are the alignment of the driving pinion bracket A, the driving shaft bracket B, the feed shaft bracket C, and the housings; only one housing D is shown. The hubs on the brackets have clearance in cored holes in the bed. It is the general practice to bore out the table spindle hole E, and table gear pinion hole F, by means of a boring jig, previous to aligning the brackets; hole F in the bed is then used as a starting point for the aligning operations.

For convenience in setting bracket A, which forms the lower bearing for the table driving pinion, and also carries inner bearings G and H for the driving and feed shafts, the bed casting is turned bottom side up, the process being as follows: The table pinion is placed in position in its hole F, for the purpose of centering the bracket; next the driving shaft I is put in place in its bearing G, and then the bracket is squared with seat J by means of a square held against the seat and the shaft. This setting is for marking off the bolt holes in the bed, and after the drilling and tapping is accomplished, the bracket is reset in the same manner as before and clamped by its bolts; then the dowel pin holes are drilled and reamed, and the pins fitted.

The next logical step is to turn the bed right side up and place reference lines on seats J and K respectively. A separate operation

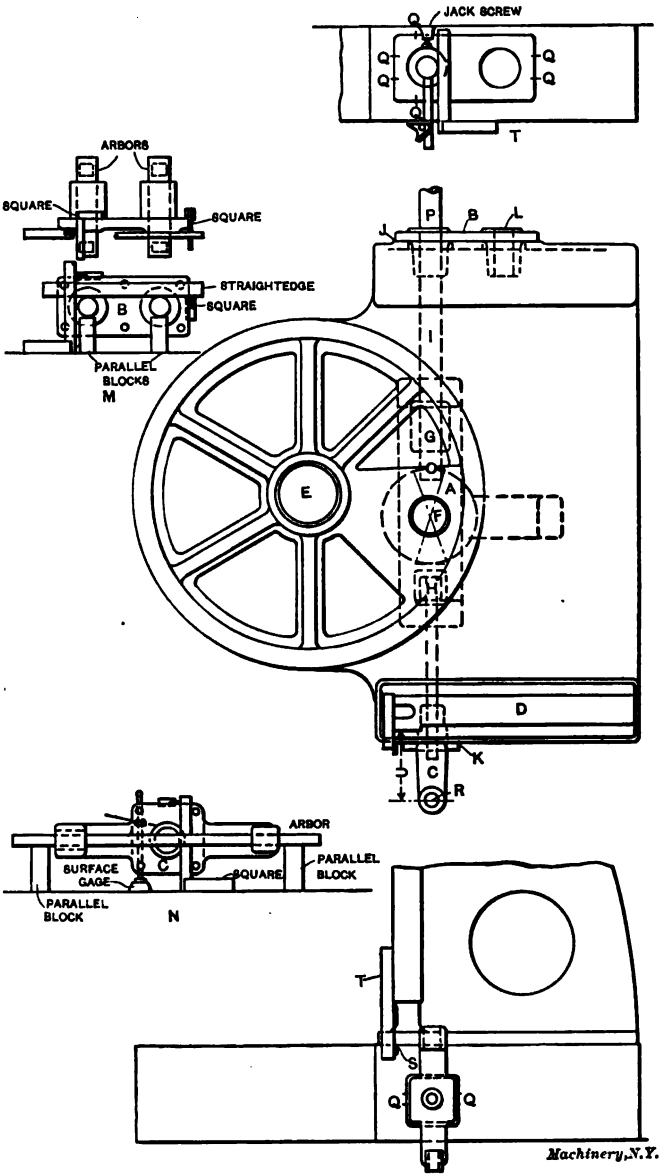

Fig. 29. Laying-out and Aligning Operations on a Vertical Boring Mill of the Spur Gear Driven Type. By the Method shown, no Special Gages or Tools are required

involves placing reference lines on the bracket members *B* and *C*. The reference lines represent, on each separate member, the outside diameter of the shaft used in aligning; then, in assembling the bracket members on the bed for the aligning operations, it is simply necessary to match the lines on the brackets with those corresponding on the bed. During this operation the brackets are supported on screw-jacks. This method of setting brackets illustrates the second point stated above, the employment of efficient means to compensate for the deflection in aligning arbors when the bracket seats lie in a vertical plane; another point of advantage, however, is that this method insures proper alignment of the shafts, any inaccuracy in the machining of the seats being immediately apparent when the members are assembled. For instance, another method of setting the driving shaft bracket would simply be to place the bracket in position on its shaft, support it on screw-jacks, and then shift the bracket around until a feeler indicated that all sides of the bracket were tight against its seat on the bed, attention being paid, of course, to the location of the back-gear hole *L* with reference to the top of the bed. With this method it would be possible to have all sides of the bracket tight against the bed as just explained, but in the event of the bracket seat not being perfectly square with the hole, the shaft would be thrown out of proper alignment with reference to the planing on the bed and also to hole *G*.

Turning back now to the question of reference lines, the method of placing these lines on the driving shaft bracket is clearly illustrated at *M* in Fig. 29, while at *N* is shown the same operation on the feed shaft bracket; both cases are essentially the same. To place lines on the bed seat *J*, a surface gage is first set to the driving shaft at *O*; next the gage is moved to position *P* and the shaft jacked up until the surface gage indicates parallelism with the top of the bed; and then, after testing the shaft with a square on seat *J* to insure that the screw-jack is not holding the shaft out of alignment sideways, a combination square and an ordinary square are used as shown at *T*. Similar operations are involved on seat *K*. Permanence is given all reference lines by driving a thin chisel into the casting directly on the line. These lines are indicated in the engraving by the letter *Q*.

The housings are located on the bed with reference to hole *R* for the vertical feed shaft. Previous to placing the housings on the bed, however, lines are drawn at *S* on each housing and on the bed casting, which lines are in the same plane as the front face of the housings. This is accomplished in the former case by means of a straightedge *T*, and in the latter case by laying off on the bed the correct distance from the center line of brackets *A* and *C*. In placing the housings on the bed the corresponding lines on each member, are matched, and then the housings are moved so that measurement *U* is correct; this measurement is taken with a straightedge and combination square. The housings are set for the pinning operations in the same manner. It may be of interest to state that the housings are first set on a large surface plate for the purpose of bolting on the arch casting and fitting the top-works, thus enabling the accomplishment of several operations

simultaneously, as the cross-rail gibs also can be laid out at this time.

By observing the third principle laid down before, the avoidance of assembling all the correlated members for the laying-out operations, it is often possible to advance work that otherwise could not be accomplished. This point is illustrated in Fig. 30, which shows an oil pumping arrangement attached to an engine lathe carriage and driven by a shaft carried in bearings on the back of the bed. This outfit is special in its nature and is furnished as an attachment; considering this fact it will be apparent that the bed member is likely to reach the assemblers last, and therefore the work can be greatly advanced by laying out and fitting up the carriage members independently of the bed.

After bolting the oil tank *A* to carriage *B*, its bolts fitting T-slots in the carriage, the oil tank is set and then dowel-pinned, the operations being so simple as to need no explanation. As bracket *C* is already bored out on a boring mill, the first laying-out operation involves the location of stud hole *D* in the oil tank. Since this hole must be laid out with reference to surfaces *E* and *F* on the bed (surface *G* on the carriage is merely planed for clearance) very effective use can be made of a jig consisting of a short bed section; but if this is not available, a gage block *H* similar to that used in planing the carriage, can be substituted. A graduated try-square is used first on surface *E* and then on surface *F*; the measurements are read directly from the graduations. Next, the hole is drilled and tapped using a pneumatic drill, and then bracket *C* is clamped in place by the intermediate gear *I*.

The next operation involves the alignment of hole *J* with reference to surface *E*, the object being to provide standardization for the planing of shaft bearing *K* and its seat on the bed. This is accomplished by swiveling bracket *C* around, using stud *I* as a pivot, until a combination square and scale indicate that the measurement is correct. The slide of the combination square rests against surface *E*, while its base is held in contact with surface *F*; the scale is then used to measure from the combination square slide to the center in the hole. After the bolt holes *L* and *M* are located, drilled and tapped, bolts are entered and the bracket is reset for pinning; the clearance in the bolt holes permits of adjustment.

To set the oil pump *N* it is merely necessary to bring gears *O* and *P* into proper mesh. The driving shaft brackets on the bed, one of which is shown at *K*, are located as follows: A short arbor representing the driving shaft is inserted in the bearing hole, and then the measurement is taken from surface *F* on the bed. These brackets are located and drilled on the bed while it is under a radial drill for other drilling operations, and the bed is turned over on its side at this time for convenience. The dowel pin holes in the driving shaft brackets are not drilled until all the parts are assembled on the bed; then the final alignment is accomplished by moving the carriage close to each bracket alternately and slackening off the bolts, thus allowing the adjacent bracket to be self-aligned, after which the bolts are tightened for the pinning operations.

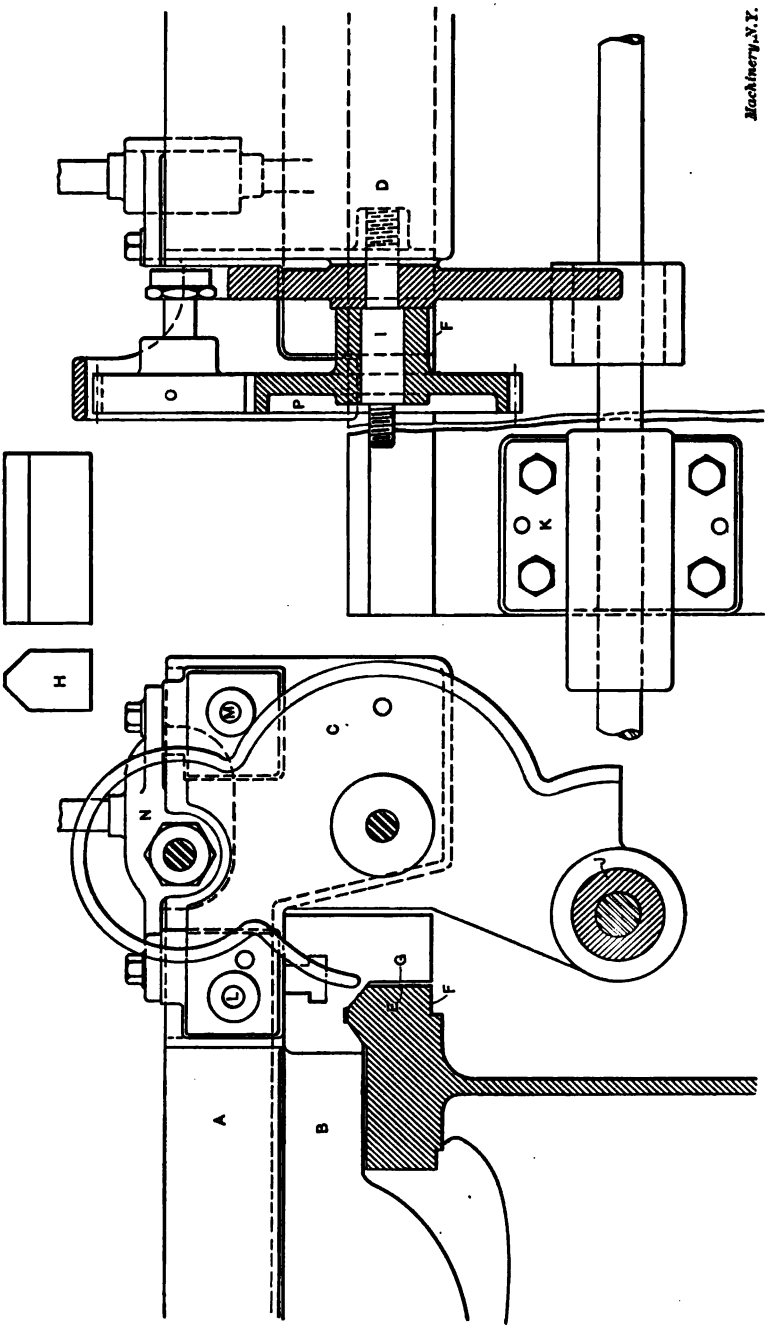

Fig. 30. Method of Laying Out and Aligning an Oil Pump Attachment on an Engine Lathe. Illustrating the Principle of Avoidance of Assembling all the Members together for the Laying-out Operations

Laying Out Angles

In machine tool work it frequently becomes necessary to lay out angles, and as a general rule it may be stated that a much greater degree of accuracy can be obtained by the following methods than is possible by laying off angles with the ordinary bevel protractor made for machine shop work. The correctness with which an angle can thus be produced, however, naturally depends on the skill of the workman in working to the scribed lines and on the accuracy with which they have been located. If it is not convenient to lay off the lines directly on the work, the given angle or taper may be laid off on a piece of sheet steel, which is then carefully filed to the lines scribed thereon.

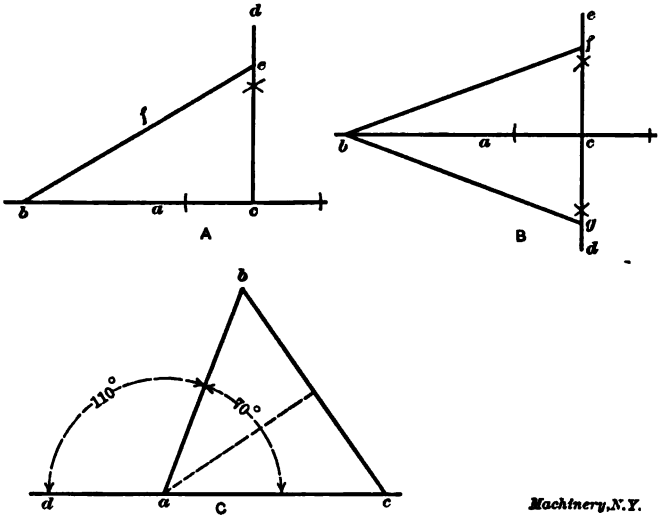

Fig. 31. Graphical Methods of Laying out Angles

Scribe a straight line *a*, as at *A* in Fig. 31; then make two very fine center punch marks, *b* and *c*, on this line, as far apart as circumstances will permit. At *c* erect a perpendicular, as *cd*. The distance *bc* being laid off to some convenient dimension, take the tangent of the required angle and multiply the distance *bc* by this tangent, using a table of natural tangents. Then, on *cd* lay off as accurately as possible the product of *bc* and the tangent, marking it by a fine center punch mark as at *e* on the line *cd*. Scribe a line through *b* and *e*; the angle *ebc* will then be the required angle.

When the required angle is greater than 45 degrees, it is more convenient to use the method shown at *B*. Scribe the line *a* and on it lay off *bc* as long as convenient. At *c* erect the perpendicular line *de*. From a table of natural tangents take the tangent corresponding to one-half the required angle; multiply the distance *bc* by this tangent and lay off the distance thus found on both sides of *c*, marking it at *f* and *g*. Join *f* and *g* to *b* by straight lines. The angle *fbg* is the required angle.

When the required angle is greater than 90 degrees, instead of laying off that angle, its supplement is laid off. Subtract the required angle from 180 degrees and lay off the angle thus formed. Thus, if the required angle is 110 degrees, lay off the angle *bac*, as at *C*, Fig. 31, equal to 180 degrees — 110 degrees = 70 degrees by the method illustrated at *B*. The angle *dab* is then 110 degrees. All other factors remaining as before, the accuracy attainable will be greater as the base line, as *bc*, at *A* and *B*, or *ac*, at *C*, is made longer.

The laying-out and aligning operations on machine tools require, as we have seen, a thorough understanding of the purpose of the various parts making up the machine, and the accuracy required in their alignment. Besides this, a general knowledge of elementary geometry is not only helpful but in many cases almost indispensable. The examples of aligning operations given in the present treatise are, of course, intended to be primarily of suggestive value. Individual judgment will have to be used in each particular case, and definite rules cannot be laid down that would be applicable under all conditions. The general outlines presented above, however, and the simple methods given for the laying out of angles will be found useful in operations of this kind not only on machine tools but on all classes of machinery where the accuracy of the alignment of interdependent parts is necessary for the successful working of the machines.

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